THE OHIO JOURNAL OF SCIENCE

VOL. XXVI NOVEMBER, 1926 No. 6

THE SOCIAL SIGNIFICANCE OF SCIENCE.*

PAUL M. REA

BEGINNINGS OF SCIENCE.

Insatiable curiosity is one of the most important characteristics of the human mind. From his earliest days to the present, man has observed and wondered and been ill at ease until he has found satisfactory explanations of natural phenomena. Every primitive people has these explanations. However fantastic they may seem to us, they are nevertheless just as reasonable as our own when consideration is given to the limited experience and knowledge on which they are based.

These primitive explanations of natural phenomena are no sooner formulated than they begin to be modified by further experience. Here are the beginnings of philosophical and religious speculation and of science. Religious speculation is primarily concerned with the unknown, philosophical speculation with the projection of the known into the unknown, and science with the known. The early progress of science is excessively slow. The power of tradition is great and old beliefs give way but slowly to new ideas. Step by step, however, naturalistic ideas make inroads upon the field of pure imagination. There is never-ceasing conflict between tradition and new knowledge.

The field of the known is ever increasing, but the unknown ever extends limitless beyond. Some minds find satisfaction in the known. Some are chiefly concerned with the unknown but apparently knowable borderland. Some find compelling fascination in the further distances of the unknown where imagination can have free play.

* Presidential address at the Thirty-sixth Annual Meeting of the Ohio Academy of Science held at Columbus, Ohio, April 9 and 10, 1926.

THE PRICE OF SPECIALIZATION.

These three interests have been characteristic of all ages. The great change that has taken place is the stupendous increase in the scope and complexity of knowledge. This has had two momentous consequences. The first of these is that no thoughtful person can now orient himself toward life and environment without a broad understanding of science. The second is the increasing difficulty of acquiring such an understanding. The time when an alert mind could fairly comprehend the sum of knowledge is not far behind us, but it is gone beyond recall. The problem before us is to find means of maintaining a broad culture in the midst of ever-increasing specialization upon ever-decreasing segments of knowledge. The solution of these problems requires an interest in imparting knowledge among those who know and an interest in receiving knowledge among those who do not know. Most of us are among those who know in some small field and among those who do not know in many other fields. However dangerous a little knowledge may be, one of the real needs of modern society and one destined steadily to increase, is for accurate general information. The urgency of this need in respect to the field of science can be appreciated only after some consideration of the influence of science upon modern society.

THE YOUTH OF MODERN SCIENCE.

Our own civilization and social structure is of recent origin. Its immediate beginnings are to be found in what we call the Renaissance. This was a profound but gradual change resulting from the freer circulation of men and thoughts associated with the Crusades, with the widening of the horizon by travelers like Columbus, with the invention of printing, the re-discovery of Greek culture, the development of universities and learned societies, the establishment of museums and botanical gardens. It was a period of revival of interest in learning, and it was beginning to bear complex fruits in the Sixteenth Century.

Our culture is thus built in part upon the culture of classic Greece, in part upon the learning of our own period. Slowly during the early part of this modern period scientific methods were perfected and fundamental concepts of science established. With these foundations laid, an ever-increasing acceleration of scientific progress has ensued.

OUR SCIENTIFIC AGE.

One of the results of modern science has been the growth of our present civilization upon a foundation of applied science. The life of the people is conditioned largely by the utilization of natural materials and forces made possible by science. The mechanisms of applied science and the industrial processes by which they are produced have a major influence in determining the environment, the occupations, and the habits of thought and behavior of mankind. Science makes the preparations for our reception into the world, prescribes the diet, clothing, and daily routine of the infant, provides the houses in which we live, together with our food, fuel, water, light, furnishings, and multiple labor-saving mechanisms. Science determines the occupations of most of us, and where and under what conditions our working life shall be spent. Science provides the means of transportation and thus controls the range of our movements, a large part of our play, and the breadth and nature of much of our thinking. We depend upon science to keep us well, and we turn to science when we are ill. It is no wonder we boast that we live in an age of science!

EFFECTS OF SCIENCE.

These profound changes in human life are the results of applied science. They are of such recent development and of such obvious portent for good and evil that they require the most serious consideration of mankind. In so far as they facilitate the meeting of the primary necessities of life, conserve health, broaden the horizon of our experience, and increase leisure, they ameliorate the harshness of a more primitive manner of life and open possibilities for the enrichment of life. Whether at the same time they soften the fiber of the people and sow the seeds of decay in the civilization of which they are the outstanding characteristic, is uncertain. We know, although we may not always remember, that throughout the long history of life every great expansion has been followed by a decline to extinction or obscurity. Every human civilization has flowered only to decay. In no nation and at no time in history has prosperity been so nearly universal as it is with us today. By all standards of the past we are now arriving at a pinnacle never surpassed. In the very greatness of our achievement we cannot but sense a note of warning. If our material

prosperity leads to habits of luxury and indulgence, to indifference to the fundamental problems of individual life and of society, our prosperity may well become a curse. If, on the other hand, our increasing knowledge and leisure lead to the enrichment of our individual inner lives, to a greater interest in a more intelligent approach to the multitude of unsolved problems of society, we may well hope to continue our progress in the building of a finer social structure and a greater personal happiness than any people has yet attained.

It is not conceivable that the progress of science will soon be retarded. We must rather expect an ever-increasing acceleration and an ever-increasing complexity of life resulting from this acceleration. Our main reliance must be placed upon more science; not merely in the production of more mechanisms, but especially in those fields of science which hold promise as yet but dimly apprehended of a truer knowledge of the reactions of men to their physical environment and to their social contacts with one another. The increase of happiness in the broadest and highest sense of the word, happiness not of a favored few but of all, is a worthy object of human endeavor.

THE SPIRIT OF SCIENCE.

Applied science is undoubtedly highly appreciated by mankind, but the spirit of science is far from being generally appreciated. The great contribution of science to humanity lies in its indefatigable industry in accumulating facts, in its honesty in facing whatever facts are found and whatever principles those facts may indicate, and in its open-minded readiness to modify its opinions in the light of new evidence. We cannot have true science without sincerity in the search for truth and without the realization that most truth is relative. The attitude of science stands in sharp contrast to the attitude of the unscientific, which is controlled by tradition and by emotion. Prejudice and lack of understanding of science, especially biological science, is one of the handicaps in the intellectual adjustments of the people to the progress of knowledge and in social practice and legislation.

The mechanistic products of science are quickly accepted by the people. So largely do these utilitarian results bulk in the popular mind that they are all too commonly regarded as the sole purpose of science. "Of what use is it?" is the first question of such minds regarding knowledge. It is of the greatest

importance that the general public learn to appreciate, first, that useful inventions are invariably developed from apparently useless knowledge—there can be no applied science until we have science to apply—and, second, that the mechanisms of civilization are but the paraphernalia of life, that the most precious human experience, the highest form of happiness, lies in harmonizing the experiences of life and in adjusting ourselves satisfactorily to life and to our environment. This orientation of one's self in life has been from time immemorial the great desire of human beings. Science is rapidly providing a necessary basis for this orientation. Never before in all the long millions of years of the history of life, we may be sure, has any species ever before attained an objective point of view toward itself, projected its mind into the magnificent distances and dimensions of astronomy, into the remote time of geological history, into the minute realms of chromosomes, bacteria, atoms, and electrons.

Even today we are just beginning to apprehend what natural history means, beginning as it does in infinitely remote time and space, sweeping like a great stream through the ages, seeming to pause a moment in the eddy of our personal experiences, and sweeping again in full flood toward an infinitely remote future. Only with some understanding of these major concepts of science can we hope to experience the full richness of modern life, or to make such adjustments in our attitude toward life as are worthy of the minds with which we are endowed, and of the rich race experience that is our heritage.

THE SOCIAL DUTY OF SCIENTISTS.

It takes many men of many kinds to make a world. Scientists tend to withdraw themselves from the turmoil of practical life, to associate with kindred minds, and to seek the seclusion of the laboratory and the study. This is appropriate in so far as it facilitates that concentration which is essential to research, yet it is but the first step in meeting the social need of science. Some fortunate scientists are able to emerge from the cloister either in person or through the written word with a message of great import to humanity. These perform a social service of the highest order. I conceive one of the great needs of society today to be the provision of more effective means for the interpretation of science to the general public.

The progress of science is recorded by custom in technical publications. These are a necessary and admirable means of communication between scientists of the present and of the future. It must not, however, be forgotten that these technical publications are written in a dialect incomprehensible to the people, and that the ultimate end of research is to contribute to society. Society needs accurate and judicious interpretation of science.

SCIENCE IN EDUCATION.

One of our most characteristic institutions for the interpretation of knowledge is our educational system. Since we are living beings in a world of nature, it would seem that no college course would be complete without a serious presentation of what is known about life and its environment. In actual practice, however, science occupies a much more subordinate position than would seem natural from our present point of view. I attribute this to two general causes. First, failure of the general public to appreciate the magnitude of the concepts science has to offer. Second, the failure of science faculties to appreciate how much more important the major concepts of the sciences are in education than the minutiae.

I well remember how in my college days I was thoroughly imbued with the idea that science is a very serious matter; that I must train my powers of observation by prolonged search for minute facts with the careful recording of my observations in notes and drawings, and that only by long practice in small generalizations might I come in time to understand the spirit and the broader conclusions of science. Looking back I find no fault with this experience as a foundation for science as a profession. I am impressed, however, by the very small proportion of college students who go far enough with such a program to obtain the kind of understanding of science that ought to be a part of the equipment of every college graduate.

Even in the most intellectual circles of a great city I hear little discussion of most of the subject matter of my college courses in science. Principles of erosion, Boyle's law, chemical formulae, Amoeba, the anatomy of the earthworm, alternation of generations, the germ layers, are not subjects of general conversation. I do hear, however, at the round tables in the clubs, at social dinners, in short wherever intelligent men and women gather together, expressions of vivid interest in scientific

events and discoveries. I take as my type of the better element of the general public the successful business man and his family. They are endowed with good minds, they are well educated, they are deeply immersed in the problems of their vocation, they are of an inquiring disposition, they want to know what is happening in the world and what it signifies, they desire culture but find it rather difficult to attain. They are interested in events and the significance of events. Their interest does not begin with general principles and proceed to the illustrations. It begins rather with particular events and is not satisfied until the principles that give them significance are indicated.

My experience suggests that a sharp distinction should be made in the college curriculum between courses of professional training and courses of general culture. However assured we may be that one cannot fully comprehend a scientific problem except by studying all its details, we must admit that one may at least apprehend a principle from consideration of conspicuous illustrations.

The successful college course must meet two fundamental conditions. It must present accurately and in due proportion the important concepts of the subject. It must also make the largest possible contribution to the enrichment of the mind of the student. The student's needs may best be understood if we consider what influence the subject matter of the course may be expected to have upon his later life. The success of the course will be proportionate to the degree to which it illuminates his experiences.

One of the best popular lecturers on astronomy that I know is a lawyer to whom astronomy is a recreation. Popular audiences are fascinated by his astronomical descriptions. Their effect is to broaden the mental horizon of the hearers, and to give significant facts that may serve as the nuclei around which may adhere ideas obtained from other sources.

In practical life most people are not interested in mathematical physics or in chemical formulae, but they are greatly interested in the nature of matter and the inter-relations of its various forms as seen by the physicist and the chemist. In geology they are not interested in the intricasies of crystallography, but they are greatly interested in the history and structure of the world in which they live. In biology they are not interested in the anatomy of animals that are for the most part outside their experience, but they are deeply interested in

the living things about them, or which come into their experience through the work of expeditions. Whenever their attention is drawn to facts, their minds are receptive to an explanation of the significance of the facts.

NATURAL HISTORY.

A hundred years ago natural history was a term in general use to cover the field now apportioned among the sciences of astronomy, geology, paleontology, biology, and anthropology. The increasing complexity of these sciences has obscured the fact that they are but different aspects of one great unit—nature. There is already noticeable in college curricula a tendency to overstep these departmental fences and to offer courses of increasingly broad scope. This is the logical step toward meeting the needs of students who take science for general culture. General science is a rather heavy and uninspiring title. The good old term, natural history, is coming back into use. I commend it to the consideration of the colleges for the richness of its connotation and the directness with which it describes the kind of science for which I find so great a need in society.

THE SOCIAL NEED OF SCIENCE.

At best a college education opens the doors ajar to a series of fascinating vistas of human thought and experience. Among these a student can hardly select more than one for intensive exploration in later years. There is an inevitable tendency for the other doors to swing to and leave the vistas to which they lead as mere memories. There is increasing consciousness of a real social need for means of maintaining the vividness and extending the richness of college experience. There is also an increasing consciousness of the social need of better methods of interpreting knowledge to those who have not had college experience. These needs are evidenced by the space devoted to science in newspapers, magazines, and books; by the popularity of lectures; and by the conversations of social groups.

MUSEUMS AS INTERPRETERS OF SCIENCE.

As agencies of public education, museums are coming to perform an increasingly important social function. In this country the museum movement is older than the nation. It began with the founding of the Charleston Museum in Charles-

ton, South Carolina, in 1773. This founding, curiously enough, was an expression of a part of the Revolutionary spirit. The committee which founded this institution included Charles Cotesworth Pinkney, and its minutes state that it was animated by a desire to show the intellectual independence of the Province of South Carolina from the mother country.

In more than 150 years since the initiation of the museum movement in America, there have naturally been many phases of museum development. Between 1814 and 1826 there was in Charleston an intensity of public interest in museums astonishing to contemplate. "The State Legislature and the City Council, alive to the importance of this object, with a promptness and liberality, which will forever redound to their credit," made the first appropriations of public funds for museum purposes on record in this country, and these appropriations, together with sums subscribed by individuals, were applied to the purchase of an extensive natural history collection brought to Charleston by Dr. Felix L'Herminier. South Carolinians in the diplomatic service procured extensive foreign collections for the enrichment of the museum; among these was the Hon. Joel R. Poinsett, minister to Mexico, from whom the Poinsettia is named. The collections were described as rich in minerals, fossils, and shells, in ornithology, herpetology, ichthyology, and entomology. There were 800 mounted birds, 70 mammals, 200 fishes, and 4,000 minerals. The exhibits were arranged in glass cases, and the museum was advertised as "open every day from nine o'clock, and brilliantly illuminated every evening." An editorial in the *Courier* of November 23, 1824, contains this remarkable statement: "In these enlightened times, a public museum is as necessary an appendage to a city, as a public newspaper or a public library."

This extraordinary activity of a museum as a public institution was not without parallel in other cities, notably Philadelphia and Salem, Mass. Museums of this type were usually founded by societies.

Early in the Nineteenth Century two other classes of museums were conspicuous. One is that of the scientific societies, among which are conspicuous the Academy of Natural Sciences of Philadelphia, founded in 1812, and the Boston Society of Natural History, founded in 1830. These museums were primarily of the research type. The scientific publications based upon them mark milestones in the progress of American

science, but these museums have not been adapted to the performance of the functions of public museums as we now conceive them.

The second class of museums conspicuous in the first half of the Nineteenth Century was the college museum. Most of the colleges of the period were denominational colleges. Nearly all of them maintained chairs of natural theology. The principal thesis of these chairs was the evidence of the nature of deity as shown in the complexities and adaptations of creation. The museum of natural history was the laboratory of the chair of natural theology. It had a profound influence upon the college graduates of the period, and as they traveled to the far corners of the earth they sent back to the college museum new examples of the wonders of creation. Museums in this period were a vital part of our colleges.

The publication of Darwin's Origin of Species in the middle of the century inaugurated a profound change in the attitude toward nature. The main thesis of the chairs of natural theology was undermined. Interest in the museums declined. A new interest arose in laboratory studies of morphology and embryology. Selected forms in quantity for dissection, and small synoptic series for demonstration replaced the museums. Departments of biology were everywhere established, usually by robbing the museums of their curators.

Approximately 38 percent of the 600 museums nominally existing in the United States belong to schools, colleges, or universities. Most of these museums have no vital college function, and a great majority are practically without funds. inactive and deteriorating.

The greatest and most active museums of America today, with few exceptions, are of a new type which may be designated, for want of a better term, as public museums. Some of the greatest of these were founded in the last quarter of the nineteenth century, including the American Museum of Natural History, 1869, the New York State Museum, 1870, the Milwaukee Public Museum, 1882, the Brooklyn Institute of Arts and Sciences, 1889, the Carnegie Institute Museums, 1896. Public museums have two outstanding purposes. Research for the increase of knowledge, and the interpretation of science to the people for the enrichment of life. These museums are usually supported by a combination of private and public funds. Their importance to society increases with the urban

concentration of population. They stimulate and guide interest in local natural history and they bring the natural history of the far corners of the earth into the city for educational purposes. More and more these public museums are becoming the centers of the science interests of their communities.

THE SCOPE OF MUSEUMS.

In contrast to the university, the museum deals potentially with the whole public almost literally from the cradle to the grave, while the university deals with but a limited fraction of the public enrolled from four to eight years. Where the university's instruction is intensive, that of the museum is extensive. The university represents a concentrated molding and directing influence upon the early years of adult life; the museum combines instruction with recreation, and stimulates rather than compels attention. Public museums work in close partnership with the public schools, where they have an important and unique social service to render.

MUSEUMS IN ADULT EDUCATION.

In adult education these museums have an equally important service to perform. They offer one of the most promising means of continuing and developing through adult life the interest in science that is created in college, and to the non-college public they afford a substitute for college training in science. Up to this time adult education in museums has been chiefly through the arrangement and labeling of exhibits, and through lectures given in the museum or before other organizations.

The great reserves of material necessary for the technical work of museums have not hitherto been effectively utilized for any form of adult education. There appears to be here a fertile field for development. Experiments on a small scale indicate that it is quite possible to bring small classes of adults into reserve collections, and that the offer of this service will be eagerly accepted by the public. These groups should be given organized instruction quite different from that of regular or extension university courses. Appointments of an hour and a half each, once a week for four weeks, offer sufficient opportunity for a cultural experience of distinct social value. Such brief courses can be taken without too great disorganization of the complex activities of adults. The most accessible

clientele for such cultural courses will probably be found among intelligent women who can take these courses during the day. In order to reach men it will be necessary for the museums to provide evening instruction.

Among public museums we can already find some of the most fundamental thinking and skilful methods for bringing about a sympathetic understanding between technical scientists and the general public. These museums offer fascinating possibilities as the intermediate wheel to gear together the power wheel of research and the work wheel of practical life. The educational work of museums is not a duplication of school or college work, but a parallel service, and there should be close understanding, sympathy, and co-operation among these institutions. The educational departments of museums will furnish the technique of interpretation; their scientific departments will furnish the facts and principles. College scientists can make important contributions to this service and in doing so can receive valuable suggestions and stimulation.

If there is such a need as I have described for the interpretation of science to the people, and if there is need for co-operation among colleges, museums, and scientific institutions generally in this social service, the Ohio Academy of Science should have a function of significance to the whole State.

OPPORTUNITIES OF THE OHIO ACADEMY OF SCIENCE.

The Academy is the common meeting ground of the scientific activities of the State. One of its important functions is to provide a forum for personal contact and exchange of ideas that cement together in friendly association the scientific men of the State. This function is so obvious and so generally appreciated that it does not need to be stressed.

The second function of the Academy requires more thought. This is the interchange of institutional and personal programs in order that each of us may be better informed about the scientific work in progress in the State, and in order that we may co-operate more effectively in a common cause. I recommend that consideration be given to the desirability of conferences for the specific purpose of articulating more closely the varied activities in Ohio.

The third function which seems to me to devolve upon the Academy is that of presenting to the people of the State by means of special papers at the Academy meetings, and with the

organized aid of the newspapers of the State, broad summaries of the progress of science in the State. There are two important reasons for doing this. The first is the obvious duty of scientists to contribute as largely as possible to the enrichment of the life of the people. The second is that the progress of science depends upon the financial support and social encouragement which it receives, and these can come only from a general appreciation on the part of the people of the importance of science and very clear understanding of the needs of scientific workers.

The Ohio Academy of Science has a long and honorable history. It is so constituted as to possess inherently a large potential influence. Its very nature imposes upon it a serious obligation to serve society to the best of its ability. The more intimately we integrate ourselves with the general public, the greater will be the mutual advantages to be experienced.

Science is one of the dominant factors of our age. Its complexities are bewildering. Its spirit and its meaning are but dimly apprehended by society. My plea is for the enhancement of the social value of science in the enrichment of the life of the people, in the adjustment of personal experience to the world of phenomena, and in the diffusion of the scientific spirit of indefatigable industry in accumulating facts, of honesty in facing whatever facts are found and whatever principles those facts may indicate, and of open-minded readiness to modify opinions in the light of new evidence.

PRINCIPLES OF PLANT TAXONOMY. III.*

JOHN H. SCHAFFNER

Important evidences of relationships are obtained from a study of the life cycles of plants. A knowledge of life cycles is of special importance in delimiting classes and the higher subkingdoms. In fact, the whole phyletic scheme of relationships depends to a very decided extent on the theoretical views that are held as to the origin and evolution of the numerous types of life cycles present in the plant kingdom. In general, all types of life cycles fall into two divisions, the non-sexual and the sexual.

Nonsexual Life Cycles.

In the lowest forms of unicellular plants the cycle is simply: 1. Increase in size of cell; 2. division of cell; 3. separation of daughter cells. These three primary processes are a part of all normal life cycles, whether sexual or nonsexual, from the lowest to the highest.

The first modification of this primitive cycle is a delay in the separation of the cells after division, giving rise to all sorts of colonial forms—linear, superficial, and solid aggregates of similar or undifferentiated cells. The cycle is then: 1. Increase in size; 2. division; 3. delayed separation (an intimate association of cells for a greater or less length of time); 4. separation.

The third type of nonsexual cycle is present in nonsexual, differentiated plants in which during the period of association after division, the cells are differentiated from each other, giving rise to differentiated, multicellular individuals. Among the blue-green algae, Rivularia represents such a plant with a considerable diversity of cells. The life cycle then becomes: 1. Increase in size of cells; 2. division; 3. indefinite association or hanging together of cells; 4. differentiation of cells; 5. separation of reproductive cells. These three types of cycles are also parts of the cycles of sexual plants which add two very profound stages—the fusion of gemetes and the reduction division.

* Papers from the Department of Botany, The Ohio State University. No. 175.

In the slime bacteria (Myxobacteriales) the life cycle is characterized by the association of the cell units for a long time in a pseudoplasmodium. The cells are, however, not intimately connected as in a colony or multicellular individual and at the end of the life cycle the entire mass of bacteria in the pseudoplasmodium usually builds up a complicated elevated structure or cyst which externally resembles the fructifications of slime molds and of the higher fungi.

Life Cycles of Sexual Plants.

THE NEMATOPHYTA.

The development of sex in the organic kingdom represents one of the most remarkable or perhaps it might properly be said the most remarkable event in the whole history of evolution. At a certain stage or period, cells develop primary sexual states and react toward each other in such a way that they are attracted and fuse. We say the one is in the female state or (+) and the other in the male state or (—). This union of cells is just as remarkable, and so far an unexplainable process, as that other more primitive process, cell division. The lowest gametes are isogamous and these lead up to the higher, heterogamous condition. The union of the gametes and their nuclei, however, does not involve the union of the chromosomes, which remain as distinct individualities and are thus doubled in the zygote. Fertilization which properly means conjugation, therefore, requires an "undoing" process or segregation process to separate the chromosomes into two complements with the original numbers. The reduction division is a necessary complement of fertilization. At reduction, the individual pairs of chromosomes or synaptic mates are sexualized and conjugate in the nucleus and are then segregated by the law of chance into the two resulting daughter nuclei. Conjugation or fertilization takes place between the sex cells which are normally haploid and have the primary sexual states. The reduction division normally takes place, in the various groups of plants, at three definite points giving rise to three general types of life cycles, the simple haploid sexual cycle, the simple diploid sexual cycle, and the alternation of generations cycle. In the diagram below, the main types of life cycles and some of their modifications are represented.

The life cycle of the unicellular sexual plants, to whatever group they may belong, is a modification of the unicellular nonsexual cycle thru the development of sexual states at certain periods. Sphaerella is a typical example: Single haploid cell; increase in size; division; isogametes; discharge of gametes; conjugation; resting diploid zygote; germination of zygote with a reduction division giving rise to four reduction spores; development of the spore to a normal unicellular individual

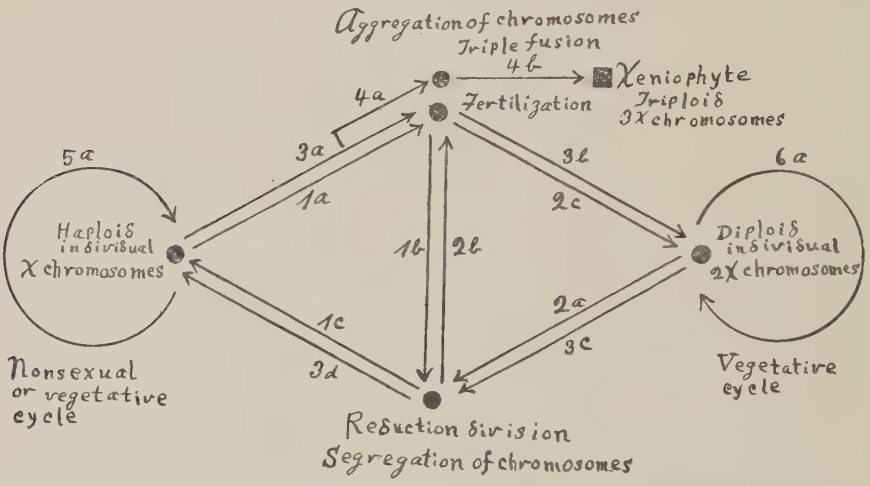


Fig. 1. Life cycles of organisms, generalized diagram. From the winter's "Laboratory Outlines for General Botany." Fifth Edition.

1. Simple sexual cycle, the individual being haploid. Haploid gametophyte—fertilization—reduction (1a-1b-1c).
2. Simple sexual cycle, the individual being diploid. Diploid gametophyte—reduction—fertilization (2a-2b-2c).
3. Life cycle with antithetic alternation of generations. Haploid gametophyte—fertilization—diploid sporophyte—reduction (3a-3b-3c-3d).
4. Life cycle with antithetic alternation of generations and xeniophyte. Haploid gametophyte—fertilization and triple fusion—diploid sporophyte and triploid xeniophyte—reduction (3a and 4a—3b and 4b—3c—3d).
5. Haploid vegetative and non-sexual spore propagation (5a). This cycle also represents the primitive nonsexual cycle.
6. Diploid vegetative and nonsexual spore propagation (6a).

which may divide vegetatively for some time. (See Fig. 1. 1a - 1b - 1c.) In the colonial forms and those with differentiated multicellular body, the life cycle is the same except that in the vegatative period the cells hold together.

All three types of general life cycles found in the Nematophyta probably originated directly from the unicellular condi-

tion and consisted of a two-phased condition represented by a haploid and a diploid cell as in Spharella. In the higher development of the simple, haploid sexual cycle, the main evolution was in the multicellular development of the vegatative, neutral phase. In Coleochaete there was an addition of vegetative divisions before spore-formation following the reduction division in the zygote. This multiplication of divisions after reduction is known in other plants and in certain animals. It does not represent a true alternation of generations. In Coleochaete the individual is haploid, in Fucus it is diploid. In both cases the multiplication of cells after the meiotic phase is to be regarded as a vegetative intercalation.

If a vegetative multicellular phase is developed between fertilization and reduction, a simple, diploid, sexual cycle becomes established as in animals, Charophyta, and Fucaceae.

If the original haploid unicellular plant evolves a multicellular haploid body and at the same time intercalates a vegetative phase between fertilization and reduction thru a delay in the time of sexualization of the synaptic mates and if this intercalated phase results in a diploid multicellular body, the result will be an antithetic alternation of generations. This life cycle is present in some of the red and brown algae and especially in the typical antithetic cycle of all the meta-thallophyta. The term alternation of generations is often used in a very loose way to designate life cycles of very diverse types. Animals, Rockweeds, and Spirogyras, for example, do not have an alternation of generations. With the evolution of the sexual state the life cycle established depends then on the stage at which sexualization of cells (gametes) takes place, the time at which sexualization of the synaptic chromosomes (reduction) takes place, and the point or points of the life cycle at which vegetative growth and differentiation take place. As stated above, there are three primary types each with its particular stage at which reduction takes place. The three sexual cycles can then be modified in various ways by changes or modifications of the time of sex determination, loss or partial loss of primary sexual states at given points in the cycle and intercallations of vegetative divisions at various points.

Myxomycetae. The Myxomycetes must be regarded as plants which were highly differentiated in certain functional processes while still in a rather primitive morphological condition. Their nuclei are well organized. They are not to be

regarded, as has commonly been the case, as primitive plants. They are on a much higher level than the Schizophyta. The life cycle in the typical forms seems to be as follows: Vegetative haploid plasmodium; beginning of sporangium stage with conjugation of pairs of nuclei; later stage of sporangium with diploid nuclei; reduction division resulting in the production of the nonsexual haploid resting spores; liberation of zoospores from the resting spores; amoeboid protoplasts; coalescence of amoeboid protoplasts to form the plasmodium.

ZYGOPAYTA. In the conjugates like Spirogyra there is a simple haploid sexual cycle: Nonsexual or reduction cell; development (germination proper) of the haploid gametophyte; gametes developed with slight modification inside of the cells; fertilization thru conjugation tube; diploid zygospore; resting condition; reduction division in the zygote during germination; survivial of one of the four reduction nuclei in the zygospore wall which becomes the initial cell of the new generation. There is no alternation of generations and no evidence that the group ever possessed such a condition.

GONIDIOPHYTA. So far as known all the typical green algæ have haploid individuals, except apparently some of the Siphoneæ, the reduction division taking place in the zygote. In *Codium tomentosum*, May M. Williams found that the cenocytic body contained nuclei having the diploid number of chrosomes (2x) and that reduction takes place before the formation of the gametes. Hence the life cycle is essentially like that of Chara or Fucus. Whether the Siphoneæ have this type of life cycle in general is not known. The question arises whether the time of reduction may be shifted in the life cycle of lower plants from one point to the other as the time of sex determination is shifted in the higher plants.

Since reduction normally requires two divisions resulting in four cells for its completion, the normal condition is the development of four spores or four gametes. These four cells are not to be regarded as a generation of an alternating cycle, if our terms are to mean anything in particular. If further vegetative divisions occur they are to be regarded as vegetative intercalations. If the process is leading up to nonsexual spore formation, the mass of resulting cells may for convenience be called a haploid sporophyte, as in Coleachaete, but is never to be homologized phylogenetically with such diploid sporophytes as Riccia, which has been done quite generally in the past.

Ulothrix may be taken as a normal representative of the Gonidiophyta. Its life cycle is: Haploid gametophyte; isogametes; conjugation in the water; zygote; resting stage; reduction (?); reduction zoospores; germination.

The Oedogoniaceæ have very suggestive life cycles which may throw light on the origin of some of the obscure life cycles of other Algæ and the Fungi. In general there are four types of Oedogonium. 1. Species with normal hermaphrodites. 2. Species with normal unisexual plants, the male filaments being a little smaller in size than the female. 3. Hermaphroditic species in which the normal plant produces oogonia and androsporangia with androspores, the androspores producing dwarf male filaments with spermatozoids. 4. Species in which the filaments are unisexual, but the imperfect male filament, because of incomplete sexualization, produces only androspores, which germinate to produce the dwarf males with spermatozoids. The dwarf males appear to be an intercalated generation thru the parthenogenetic development of androspores which represent original spermatozoids.

The dwarf males range in the several species from unicellular to multicellular filaments. The androspores have not lost their primary male state entirely for they are usually attracted to the oogonium and settle down on it or in the cell immediately below. The reduction division probably takes place at the germination of the zygote. The life cycle of the third type of species is therefore as follows: Hermaphroditic haploid gametophyte with incomplete male sexualization; oogonium and androsporangium; androspores and immature eggs; dwarf male; antheridium on dwarf male; mature eggs and spermatozoids; fertilization in the oogonium; resting diploid zygote; reduction division in the zygote; four haploid zoospores; germination of zoospores. Had the egg also developed a parthenogenetic female filament, the result would have been a complete but peculiar type of alternation of generations, the parthenogenetic egg and sperm simulating a megaspore and a microspore. The life cycle is evidently a direct modification of the simple sexual cycle. See Fig. 1. 1a–1b–1c.

In Coleochaete the normal, simple, haploid, sexual cycle is present except that a vegetative phase is introduced between the reduction division and the nonsexual spores, so that 16-32 cells are produced instead of the usual 4, all of which develop into zoospores. The life cycle therefore is: Haploid herma-

phroditic gametophyte; gametangia; gametes; fertilization in the oogonium; zygote; resting stage; germination of the zygote with reduction; haploid "sporophyte;" nonsexual zoospores; germination of zoospores. This life cycle seems to be directly derived from the simple, haploid, sexual cycle. Another interpretation is possible by assuming that the two or more divisions following meiosis are a vestige of repeated divisions before zoospore production, handed down from a unicellular condition, but more probably they represent a mutative addition to the original cell lineage like the extra division stage which results in a 16-celled female gametophyte in some Peperomias.

PHAEOPHYTA. The knowledge of the life histories and cytology of the Brown and Red Algaæ is still very incomplete, so it is impossible to delimit the larger groups with any certainty. A number of recent discoveries, however, make necessary a rearrangement of the classes of the Phaeophyta. All arrangements must be regarded at present as tentative.

In the Ectocarpales and probably all of the Phaeosporæ proper, an alternation of generations seems to be lacking. Of the two types of sporangia produced, the unilocular sporangia are nonsexual and develop the nonsexual zoospores. The plurilocular sporangia are the sexual organs or gametangia. In some species at least, as in *Ectocarpus siliculosus* both unilocular sporangia and plurilocular gametangia may be present on the same individual at the same time. The gametes range from isogamous free-swimming gametes to heterogamous motile micro-and mega-gametes. In some species the female isogametes settle down first and the male gametes move to them, when conjugation takes place. Is the frond of Ectocarpus and related forms haploid or diploid? and where does reduction take place? Until these questions are answered for a considerable number of genera, no final classification of the Brown Algæ is possible. The life cycle so far as known is: Gametophyte; unilocular sporangium with nonsexual zoospores repeating the gametophyte; plurilocular gametangium; gametes; fertilization; zygote.

The life cycle of Fucus is well known and is as follows: Diploid gametophyte; gametangia (unilocular); oocyte and spermatocyte; reduction divisions (meiosis); vegetative multiplication of incipient sexual cells; heterogametes; fertilization in the water; zygote; germination. This is not to be regarded

as a reduced alternation of generations as has sometimes been done, but as a simple diploid sexual cycle, with intercalation of cell divisions between meiosis and gamete maturation (development of primary sexual state.) See Fig. 1 2a–2b–2c.

The greatest discoveries have been made by Sauvageau and others in the Laminariales or giant kelps, where a peculiar alternation of generations has been established for several genera. But the real knowledge required for making proper deductions are again lacking. The large frond is apparently a diploid organism and in Chorda, according to Kylin, the first division of the primary nucleus of the sporangium is a reduction division. The sporangia are of the unilocular type and agree in this respect with the unilocular gametangia of the Cyclosporæ. The spores produced in the unilocular sporangia of Lammaria and Postelsia develop into small male and female gametophytes. The life cycle would then be: Large, diploid frond (sporophyte); unilocular sporangium; reduction division; nonsexual zoospores; germination; small haploid female and male gametophytes; gametangia; gametes; zygote; germination.

There appears to be a much closer relationship between the Lammariales and the Cyclosporæ, than between the former and the Phaeosporæ. If we regard the Fucales and Lammariales as having a common primitive origin with a simple diploid sexual life cycle, then the Fucales have evolved by simply intercalating vegetative divisions between reduction and gametogenesis while the Lammariales have developed a small intercalated or secondary gametophyte thru the development of parthenogenesis in the originally isogamous gametes produced on the diploid plant. The change took place in both male and female gametes and not in the male gamete alone as in Oedogonium. The decided change in life cycle will warrant placing the giant kelps in a distinct class as has recently been done by some, otherwise they should be associated with the Cyclosporæ.

Dictyoteae. The life cycle of these Brown Algæ indicates only a remote relationship to the other groups. Dictyotas were probably segregated directly from the primitive phaeophyte stock and developed their alternation of generations cycle immediately after passing the unicellular condition. The life cycle of Dictyota dichotoma is: Haploid male and female gametophytes; gametangia; gametes; fertilization in

the water; zygote; germination; diploid nonsexual plant or sporophyte; sporangium; sporocyte; reduction; haploid tetraspores; germination. The gametophyte and sporophyte are both prominent plants.

Rhodophyta. There are various life cycles in the red algæ but apparently all have been derived from one common type. Not enough is known as yet to make conclusive deductions. The life cycle of Polysiphonia is a typical alternation of generations cycle with some complications and is well known: Haploid gametophyte; gametangia; gametes; fertilization by non-ciliated sperms in the oogonium; zygote; germination of diploid zygote in the oogonium; diploid carpospores; germination of carpospores; diploid sporophyte; tetrasporangium; sporocyte; reduction division; reduction spores (tetraspores); germination. Compare with Fig. 1. 3a–3b–3c–3d.

The life cycles of Bangia, Batrachospermum, and other genera seem to be somewhat different and Bangia and its relatives probably constitute a distinct class.

Charophyta. The stoneworts, according to the investigations of Tuttle on Nitella, have apparently a simple, diploid sexual cycle, the plant being diploid with the 2X number of chromosomes and the reduction taking place in the gametangia. Diploid gametophyte; gametangia; reduction; gametes; fertilization in the oogonium; resting zygote; germination. The stoneworts are, therefore, quite distinct in life cycle from most of the other green algæ.

Fungi.

Unfortunately, in the case of the fungi, as in various other groups of Thallophyta, the taxonomist meets with difficulty in attempting to compare the life histories of one group with another for the purpose of discovering phyletic relationships. There is much work for the cytologist. If, for example, the life history of various species of Mucor (Rhizopus) were definitely known and especially their nuclear activities during conjugation and reduction, one might be able to deduce some very important conclusions in relation to numerous experimental facts known about them as well as to their probable origin.

It is probable that in Rhizopus the reduction division takes place in the sporangium developed on the germ-tube. If this is the case and if we assume a relationship to the green

algæ with a simple haploid cycle, as for example the more primitive Siphoneæ, then the germ-tube represents either an intercalated diploid or a conjugate generation, resulting from the cenocytic development of the zygospore. Whether the conjugation of the male and female nuclei takes place in the zygospore or in the sporangium of the germ-tube is not known. It seems reasonable, however, to consider the nuclei of the two conjugating branches as having originally been incipient isogamous gametes.

In *Saprolegnia monoica* the haploid mycelium is cenocytic. The oogonial and antheridial branches are decidedly dimorphic. Several female nuclei are left functional in the female gametangium and several male nuclei in the male gametangium. The male nuclei are discharged thru a penetrating tube into the oogonium. A single male nucleus unites with each egg, thus forming uninucleate zygotes. Reduction takes place at the germination of the zygote giving rise to the vegetative haploid mycelium. This is, therefore, a simple haploid sexual cycle.

In Albugo a single male or female nucleus functions in each gametangium. The resting zygote in some species produces zoospores on germination which is probably accompanied by a reduction division.

There has been much dispute about the origin and relationships of the ascomycetous and basidiomycetous fungi. Their life histories indicate that they originated from organisms with a simple haploid sexual cycle. In the meantime, a binucleated phase has been intercalated thru the partial desexualization of the sex nuclei before nuclear fusion has taken place, the complete primary sexual state with fusion being attained again at a later stage. The conjugate nuclei have not lost their primary sexual state entirely, however, since they must exert an influence on each other, otherwise it does not seem possible that conjugate division, thru which the binucleate mycelium is developed, could be accomplished.

A number of life cycles of the Ascomycetæ are fairly well known. *Pyronema confluens* according to the work of Harper and of Claussen, has a uninucleated haploid mycelium. The essential part of the life history is as follows: The male and female sexual branches become multinucleate, fuse, and the nuclei from the antheridium pass over into the oogonium. The nuclei partially lose their primary sexual state at this

time, if it is really fully developed, and simply pair off without fusing.

Several hyphæ are produced from the oogonium and the pairs of conjugate nuclei pass into them and undergo several conjugate divisions. Thus each ascogenous hypha has binucleated cells, the pair of nuclei representing descendants of the original male and female nuclei produced. Following a complex process of division, a penultimate cell with a male and female nucleus, each with a complete primary sexual state, is finally produced and conjugation takes place, the delayed zygote. From this cell an ascus is developed in which reduction takes place giving rise to four free haploid nuclei, which with a further division give rise to the eight ascospores.

The binucleate stage arises thru the incomplete sexualization of the sex nuclei, preventing conjugation, vegetative divisions are intercalated and the binucleated condition is the result. The simulated "sporophyte" is a seconary development from an original simple, haploid sexual cycle. The binucleate phase in this case and in the basidiomycetous fungi can be called a conjugate generation. There is no evidence that the Ascomycetæ had an alternation of generations with a true sporophyte originally. In a normal sporophyte generation the nuclei are diploid, in a conjugate generation the cells contain conjugate, haploid nuclei. The generation ends by the sexualization of the conjugate nuclei and their fusion into a zygote nucleus rather than in the sexualization of synaptic chromosomes in a reduction division. Sexualization of the chromosomes with synapsis occurs at the germination of the zygote as in plants with a typical simple haploid sexual cycle. This conjugate phase seems to be developed only in the higher fungi and represents a new type of intercalated vegetative development between the fertilization and reduction stages. The fact that it is much less developed in the Ascomycetæ than in the more highly evolved Teliosporæ and Basidiomycetæ indicates that it has not degenerated from a true diploid sporophytic phase. It seems to become more prominent in the progressive evolution of the higher fungi.

The highest fungi show many of the peculiarities of the Ascomycetæ and even of the Phycomycetæ in relation to their sexual processes, indicating a close relationship as to origin. The same general method of fusion of the gametangia, the loss for a time of the primary sexual states of the conjugate nuclei,

and development to a greater or less degree of a binucleate cell condition strongly indicate a common origin, probably from uninucleate, haploid sexual green algæ with isogamous gametes which, either in the algal stage, or after passing into the fungus condition, segregated into a cenocytic subphylum and a subphylum with uninucleated cells.

In the rusts, *Caeoma nitens* may be a representative of the more primitive condition. On the other hand it is possible that it represents an abrevated life history. At present the evidence does not seem to be sufficient to establish either proposition. Caeoma has a uninucleated, haploid mycelium. In the aecium stage the tips of branches representing male and female gametangia conjugate and the contents of the one pass over into the other. The nuclei lose their primary sexual state and become conjugate nuclei. A chain of binucleate aeciospores is produced. These spores on germination become zygotes when the conjugate nuclei develop complete primary sexual states and fuse into one. In some cases at least a reduction division follows with a promycelium or basidium and four haploid basidiospores. If this is the primitive condition, it shows but a slight development of the binucleate phase. But if characteristic teliospores do develop in some unknown stage of the life cycle it would have to be regarded as a derived condition, the conjugate generation being lost thru a change in the time of the complete sexualization of the conjugate nuclei. The pycnidia may represent vestigial conidial sori.

The life cycle is then: Haploid uninucleate sexual plant; uninucleate gametangia; conjugation of cells and cytoplasmic union; partial loss of primary sexual state of the conjugate nuclei; a number of vegetative conjugate divisions resulting in the formation of aeciospores; complete sexualization of the conjugate nuclei; nuclear fusion resulting in a diploid nucleus or zygote; development of a basidium or promycelium with reduction division; four haploid basidiospores.

In some of the rusts, as in *Puccinia graminis*, the binucleated phase or conjugate generation has been extensively developed. The life cycle is: Haploid uninucleate mycelium on the barberry; uninucleate gametangia; conjugation and cytoplasmic union; pairing of the sexual nuclei without fusion; a number of conjugate divisions to produce aeciospores; germination of binucleate aeciospores on wheat; binucleate mycelium; vegetative propagation by binucleate uredospores; production

of teliospores; complete sexualization of the conjugate nuclei in the teliospore; fusion of sexual nuclei to form the diploid uninucleate condition or zygote proper; germination of zygote (teliospore) with reduction division; promycelium or basidium with four haploid uninucleate basidiospores; germination of basidiospore on the barberry again. This cycle can readily be derived from the simple, haploid sexual cycle.

The basidiomycetæ appear to present the same fundamental conditions as the other fungi, namely, a modification of the simple, haploid sexual cycle at the isogamous stage of sexual evolution. The vegetative body appears to begin as a haploid mycelium with uninucleate cells. Later cells may become cenocytic by fragmentation of the nuclei or cenocytic divisions. At the beginning of the development of the fruiting body and earlier, a conjugation of gametangia normally takes place, resulting in binucleate cells and a conjugate mycelium. A peculiar method of division of the binucleate cells gives rise to the "clamp connections" and is carried on in such a way that each cell receives a pair of the conjugate nuclei. Finally basidia are formed at the tips of hyphal branches in the fruiting body, the conjugate nuclei become sexualized in the incipient basidia, unite, and form the diploid zygotic nucleus. Reduction follows, typically with four reduction nuclei which develop the four uninucleate, haploid basidiospores.

A careful study of some of the known life cycle of the Ascomycetæ, Teliosporæ and true Basidiomycetæ shows that these groups are much more closely related than was formerly supposed. The relationship between the rusts and typical basidiomycetous fungi has been recognized for some time, but many still hold to a special origin of the Ascomycetæ. But the character of the vegetative body together with the remarkable similarity of the fundamental stages in the life cycle and the very similar sexual modifications far outweigh the slight resemblance and the duplication of superficial characters which the ascocarp may have to the sporocarps of the red algæ. The writer is convinced of the primary monophyletic origin of all the Mycomycetæ.

Life Cycles of the Meta-Thallophyta.

The Meta-thallophytes present no such difficulties or complexities in their life cycles as the Thallophytes. All the life cycles belong to a single type with clear modifications, the

typical antithetic alternation of generations cycle. The cycle simply becomes more complex with the upward progress of evolution, the fundamental stages and conditions remaining unchanged. In Fig. 2 are represented the twelve fundamental, antithetic stages, which show that there is no exactly similar life cycle in any of the Thallophytes.

The life cycles of the main groups of higher plants are given below without special discussion, since they are well known and involve no diversity of views as to their nature.

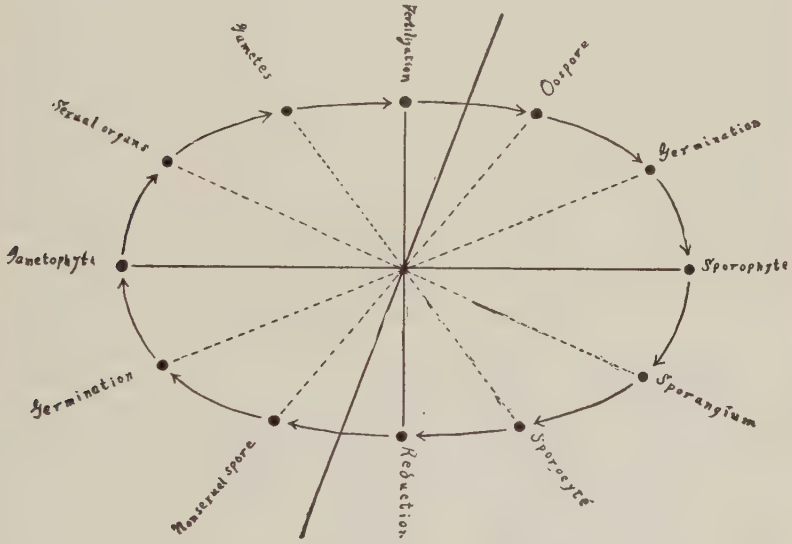


Fig. 2. Diagram showing the principal stages in the life cycle of the higher plants. From the author's Laboratory Outlines for General Botany. Fifth edition.

Whatever one may think about the origin of the antithetic cycle it is now completely established on a single type as stated above.

MARCHANTIA. Haploid male and female gametophytes; archegonium (ovary) and antheridium (spermary); female and male gametes (oosphere and spermatozoid); fertilization; zygote (oospore); germination in venter; diploid parasitic sporophyte; sporangium; sporocyte; reduction division (with primary sexual states in the synaptic chromosomes); non-sexual spores (reduction spores or tetraspores); germination on the ground. See Fig. 2 and Fig. 1. 3a–3b–3c–3d.

Typical Moss. Haploid hermaphroditic gametophyte with protonema and gametophore phases; archegonium and antheridium; oosphere and spermatozoid; fertilization; oospore; germination in venter; diploid parasitic sporophyte; sporangium; sporocyte; reduction; nonsexual spores; germination on the ground.

Typical Fern. Haploid hermaphroditic gametophyte; archegonium and antheridium; oosphere and spermatozoid; fertilization; oospore; germination in venter; diploid sporophyte with parasitic embryonic and independent mature phases and with indeterminate growth; sporophyll; sporangium; sporocyte; reduction; nonsexual spores; germination on the ground.

Equisetum arvense. Haploid male and female gametophytes which show much sex reversal; archegonium and antheridium, oosphere and spermatozoid; fertilization; oospore; germination in venter; diploid sporophyte with parasitic embryonic and independent mature phases and with indeterminate and determinate shoots; reproductive determinate shoot or flower (strobilus); sporophyll; sporangium; sporocyte; reduction; nonsexual spores; germination on the ground.

Marsilea quadrifolia. Reduced haploid male and female gametophytes (connected with the spore wall); archegonium and antheridium; oosphere and spermatozoid; fertilization; oospore; germination in venter; diploid heterosporous bisporangiate sporophyte with dependent and independent phases and with indeterminate axes; sporophyll with enclosed sporocarps; sex-determination in the sorus; megasporangium and microsporangium; megasporocyte and microsporocyte; reduction divisions; megaspore and microspore; germination in the water.

Selaginella. Reduced haploid male and female gametophytes connected with the spore walls; archegonium and antheridium; oosphere and spermatozoid; fertilization; oospore; germination in venter; diploid heterosporous bisporangiate sporophyte with dependent embryonic and independent mature phases and with determinate and indeterminate axes; bisporangiate strobilus with sex-determination in the incipient sporophylls; megasporophyll and microsporophyll; megasporangium and microsporangium; megasporocyte and microsporocyte; reduction divisions; megaspore and microspore; beginning of germination in the sporangia; completion of development of gametophytes on the ground.

Cycas. Parasitic haploid male and female gametophytes; development of pollen-chamber in the young ovule; discharge of male gametophytes (pollen grains) and pollination in pollen-chamber; development of parasitic pollen-tube and second period of development of male gametophyte; archegonium (ovary) and reduced antheridium; oosphere and spermatozoid; discharge of spermatozoids into archegonial chamber; fertilization; oospore with determination of sex; germination in venter inside of the megasporangium (ovule); embryonic diploid parasitic carpellate and staminate sporophytes; resting condition of embryonic sporophytes in the ovule (mature seed); discharge of seed; sprouting of seed in ground; juvenile independent sporophytes developing into the mature carpellate and staminate sporophytes—the former with indeterminate reproductive axis, the latter with a determinate reproductive axis, the staminate strobilus; megasporophyll (carpel) and microsporophyll (stamen); megasporangium (ovule) and microsporangium (pollen sack); megasporocyte and microsporocyte; reduction with sexualization of the synaptic chromosomes; megaspore and microspores; germination of the two kinds of spores in the sporangia.

Pinus. Parasitic haploid male and female gametophytes in the microsporangium and megasporangium; discharge of the male gametophyte (pollen) with pollination on the micropyle of the ovule; development of pollen-tube and second parasitic phase of the male gametophyte; archegonium (ovary) and reduced antheridium; oosphere and nonmotile sperms; primary sexualization of the gametes; discharge of the sperms into the archegonium venter; fertilization; germination of oospore; development of diploid parasitic sporophytic embryos (polyembryony); survival of one embryo with resting condition of the surviving embryo sporophyte in the seed; discharge of the seed; sprouting of embryo in seed; juvenile independent sporophyte; mature neutral sporophyte; determination of male and female sexual states in certain buds (monecious condition); staminate and carpellate strobili or cones (flowers); megasporophyll (carpel) and microsporophyll (stamen); megasporangium (ovule) and microsoporangium (pollen sack); megasporocyte and microsporocyte; reduction divisions with primary sexualization of the synaptic chromosomes; megaspore and microspore; germination of the two kinds of spores in the sporangia to produce the gametophytes again.

ALISMA SUBCORDATUM. Greatly reduced parasitic haploid female and male gametophytes in the megasporangium and microsporangium (ovule and pollen sack); discharge of the male gametophytes (pollen); pollination on stigma, the carpel being closed and forming an ovulary; development of pollen-tube with second parasitic phase of the male gametophyte; egg apparatus (greatly reduced ovary or archegonium) and greatly reduced antheridium (two spermatogenous cells); oosphere and two polar nuclei and two nonmotile sperms; development of primary sexual states in the five cells; discharge of the sperms into the female gametophyte; fertilization and triple fusion; diploid oosphere and triploid definitive or primary endosperm nucleus; germination of oospore and division of definitive nucleus; parasitic diploid embryonic sporophyte and parasitic triploid xeniophyte (endosperm) in the seed; resting stage of sporophyte embryo; discharge of fruit containing seed; sprouting of embryo sporophyte; juvenile stage of independent sporophyte; mature neutral diploid sporophyte; development of flower; determination of sex, originally the male state with later reversal to female state (bisporangiate flower); megasporophyll (carpel) and microsporophyll (stamen); megasporangium (ovule) in the ovulary and microsporangium (pollen sack); megasporocyte and microsporocyte; reduction divisions with primary sexualization of the synaptic chromosomes; megaspores and microspores; germination of the two spores in the sporangia to produce the parasitic gametophytes again. See Fig. 1, 3a and 4a, 3b and 4b, 3c, 3d.

Note. The differentiation of normal megaspores has been eliminated by abbreviation of the cell lineage. In many Angiosperms four megaspores are developed following reduction, one of which is functional.

CANNABIS SATIVA. The life cycle is essentially the same as in Alisma except that sexualization in the sporophyte takes place in the oospore, giving rise to the diecious condition with carpellate and staminate, highly dimorphic sporophytes. Under certain conditions sex reversal takes place abundantly in the growing sporophyte.

By comparing the life cycles from the Bryophytes to the Angiosperms it will be noted, as stated before, that they are all of one fundamental type with a gradual development of complexity in the evolution toward the highest condition.

THE GENUS MOUGEOTIA

EDGAR NELSON TRANSEAU
Department of Botany, Ohio State University

The species belonging to this genus are among the most widely distributed of all the freshwater algæ. In the vegetative condition they have been collected in arctic, temperate, and tropical regions of all of the continents and on the most isolated of the Pacific islands. They likewise occur in lakes, ponds, and temporary pools, and in all manner of springs, streams and rivers. In lakes they often form a part of the plankton either as isolated cells, or as short strait or coiled filaments. In permanent streams and ponds *Mougeotia* may be found throughout the year, while in temporary bodies of water they are among the first algæ to appear after a rainy period.

Certain species of *Mougeotia* exhibit a union of pairs of cells in adjoining filaments and a subsequent bending of the cells at the points of contact. This is known as "genuflexing" and was described by some of the earliest students of the filamentous algæ (Vaucher 1803, p. 79, Pl. 8). Some of these earlier students mistook genuflexing for conjugation, and Hassall limited the Genus Mougeotia to species that "reproduce" in this way.

Genuflexing is most frequently observed in *M. genuflexa* and its variety *gracilis*, but I have also observed it in *M. laetevirens*, *M. pulchella*, and *M. notabilis*. The phenomenon has been interpreted (1) as incipient conjugation, (2) as preparation for vegetative multiplication through the disintegration of the filaments and subsequent cell division, and (3) as a reaction for "interchange of soluble substances."

Genuflexing occurred every year in a certain pond in central Illinois from which I have frequent collections over a period of years. There it usually began early in April and continued until July or August. The mass of *Mougeotia* increased until late June or July and then decreased until there were only the usual scattered filaments the remainder of the summer. In the Autumn, vegetative *Mougeotia* became abundant, but there was no genuflexing. It is futile to assign physiological and ecological "functions" to this process since in the united knee-

joint cells, the chloroplasts usually contract and after a time the cells disintegrate and fall to the bottom. The continuation of vegetative growth comes mostly from those filaments that do not unite. Those who must have a function for genuflexing had best look upon it as a suicidal union due to unknown causes. Conjugation may occur when genuflexing is going on or at a different time. In another pond I have also observed genuflexing in which cells of two different species were united—one about half the size of the other. The species probably were *M. genuflexa* and *M. notabilis*, since both these species had been collected there previously in a fruiting condition.

In many shaded ponds in this latitude and in ponds of alpine and arctic regions vegetative growth apparently continues from year to year without change in form of the cells. Scattered akinetes (thick-walled vegetative cells) are formed. The four records from my Illinois collections falling in May, June, July and August.

Aplanospores are the only known reproductive structures in five of the species: *M. ventricosa*, *M. tropica*, *M. mayori*, *M. prona*, and *M. tenerrima*. Aplanospores are the usual mode of reproduction in *M. boodlei*. *M. calcarea* and *M. notabilis* are occasionally found producing only aplanospores, and aplanospores are usually present when these species are found fruiting sexually. Of the remaining thirty-seven species, aplanospores have been found in fourteen. We may say, therefore, that asexual reproduction by aplanospores is now known in twenty-two of the forty-five species described in this paper. G. S. West suggested that "there is in the early stages of aplanospore formation a more or less complete division of the protoplast into two parts which subsequently fuse together." This suggestion probably is based on the widely copied statement of Paul Petit that in *Spirogyra mirabilis* the aplanospores (which he regarded as zygospores) are formed in this way. I have examined hundreds of these aplanospores in all stages of development in several species of *Spirogyra*, *Mougeotia* and *Zygnema* and have never seen a cell in which the nucleus and cytoplasm divided and subsequently fused. Wittrock was quite right in his observation that in *M. ventricosa* the chromatophore *may* divide in the middle and the two halves pass into the swollen part of the sporogenous cell so that finally the nucleus lies between them. I have seen the same process in *M. boodlei*, *M. notabilis*, and *M. prona* (see Pl. VII, Fig. 111), but in none

of these did the cytoplasm or nucleus divide. In most instances the cytoplasm and the included structures merely aggregate toward the middle of the cell with loss of water and the subsequent formation of sporangium and spore walls. The initial cells of the aplanospores are usually about twice the length of the average vegetative cells, but there are numerous examples in which they are no longer than the vegetative cells.

In conjugation adjoining cells in different filaments develop protuberances which fuse and form a conjugating tube. In *M. genuflexa* and *M. scalaris* (in lateral conjugation) these protuberances may develop from adjoining cells of the same filament. Usually the protuberances are in contact from the beginning, but in many cases they are not in contact until later. I believe the same statement holds in scalariform conjugation but in that case it is impossible to prove except by direct observation.

As the conjugating tubes are being formed the chromatophores and most of the cytoplasm move into the tube, the median portions first. The tube then swells rapidly and may become several times the thickness of the filaments. The gametangia are then cut off by one, or two walls, depending upon whether or not the gametes pass completely into the conjugating tube. In the first instance the sporangium is "adjoined by two cells," i. e., the gametangia remain undivided; in the second case the sporangium is "adjoined by four cells," i. e., the middle part of each gametangium is occupied by a part of the sporangium. Subsequently a spore wall is secreted and this is usually yellow, brown, or blue, but in several species it is colorless. The spore wall may be smooth, punctate, scrobiculate, pitted or wrinkled.

Twin zygospores and combinations of zygospores and parthenospores are common in *M. capucina*. In these cases one or both gametes divide before the fusion of the gametangia (see Pl. X, Figs. 67 and 68).

The genus *Mougeotia* as here defined includes the species formerly described in the genera: *Gonatonema*, *Craterospermum*, *Mesocarpus*, *Plagiospermum*, *Staurospermum*, and *Pleurospermum*.

The writer has examined all the specimens of *Mougeotia* distributed in Wittrock and Nordstedt's Algæ aquæ dulcis exsiccatæ; Collin's, Holden, and Setchell's Phycotheca Boreali-Americana; Tilden's American Algæ; those in the U. S. National Herbarium, and other specimens sent him by the late Professor

Nordstedt, Professor Borge, (Stockholm), the late Professor Farlow, Dr. Cedercreutz, (Helsingfors), Dr. M. Higashi, (Tokio), Dr. D. B. Anderson, Dr. L. H. Tiffany, Dr. G. E. Nichols, Dr. W. M. Barrows and Dr. F. C. Baker. His own collections include specimens from most of the states east of the Mississippi River.

MOUGEOTIA (Agardh, 1824) Wittrock, 1872.

Key to the Species.

1. With aplanospores (zygospores rare or unknown)..... 33
1. With zygospores (rarely aplanospores also)..... 2
2. Sporangium between 2 undivided gametangia (adjoined by 2 cells).. 3
2. Sporangium dividing one of the gametangia (adjoined by 3 cells).. 21
2. Sporangium dividing both gametangia (adjoined by 4 cells)..... 22
3. Sporangium globose, subglobose, ovoid or ellipsoid..... 4
3. Sporangium cylindric with concave sides..... 18
3. Sporangium compressed spherical, compressed ovoid, or compressed ellipsoid..... 19
4. Spore wall smooth..... 5
4. Spore wall punctate, diam. veg. cells 11–14μ..... 16. *M. ovalis*
4. Spore wall scrobiculate, pitted or wrinkled..... 16
5. Diam. veg. cells usually less than 12μ..... 6
5. Diam. veg. cells usually more than 12μ, less than 24μ..... 9
5. Diam. veg. cells usually more than 24μ, less than 40μ..... 13
5. Diam. veg. cells more than 40μ..... 15
6. Spores globose..... 7
6. Spores more or less ellipsoid, longer axis, 20–28μ.. 2b. *M. parvula ellipsoideis*
6. Spores variable, some extending into the gametangia..... 1. *M. calcarea*
7. Outer sporangium wall a thick transparent pectic layer..... 20. *M. victoriensis*
7. Sporangium without outer pectic layer..... 8
8. Diameter spores 7–8μ..... 2a. *M. parvula angusta*
8. Diameter spores 13–24μ..... 2. *M. parvula*
9. Spores variable, some extending into gametangia..... 1. *M. calcarea*
9. Spores globose..... 10
9. Spores ovoid to quadrate ovoid..... 12
10. Sporangium wall with pectic layer, spores blue..... 19. *M. maltae*
10. Sporangium wall without pectic layer, spores brown..... 11
11. Diameter spores 23–33μ..... 3. *M. recurva*
11. Diameter spores 30–40μ..... 5. *M. scalaris*
12. Diameter spores 24–30μ, conj. lateral..... 14a. *M. genuflexa gracilis*
12. Diameter spores 40–45μ, cong. scalariform..... 10. *M. sphaerocarpa*
13. Spores more than 50μ in diameter..... 13. *M. macrospora*
13. Spores 30–40μ in diameter..... 14
14. Cong. scalariform, spores usually globose..... 5. *M. scalaris*
14. Cong. usually lateral, spores quadrately globose..... 14. *M. genuflexa*
15. Spores about 40μ in diameter..... 11. *M. subcrassa*
15. Spores 60μ or more in diameter..... 12. *M. crassa*
16. Diameter vegetative cells 8–16μ, sp. diam. less than 40μ..... 4. *M. nummuloides*
16. Diameter veg. cells 17–20μ, sp. diam. more than 40μ..... 6. *M. megaspora*
16. Diameter veg. cells 22μ or more..... 17
17. Spores globose, wall wrinkled, diameter 30μ..... 7. *M. gotlandica*
17. Spores ovoid, wall punctate, 30μ x 40μ..... 8. *M. pulchella*
17. Spore ovoid, wall scrobiculate, 38μ x 50μ..... 9. *M. robusta*

18. Spores 20μ in diameter ..... 21. *M. angolensis*
18. Spores 36–50μ in diameter ..... 22. *M. laetevirens*
19. Spores with thick outer transparent pectic layer 20
19. Spores without a thick outer layer, diameter veg. cells 7–12μ ..... 15. *M. depressa*
20. Spores brown, diameter veg. cells 13–18μ ..... 17. *M. gelatinosa*
20. Spores blue, wall punctate, diameter veg. cells 14–20μ ..... 18. *M. cyanea*
21. Spores variable, globose to ovoid or quadrate, diameter 30–40μ ..... 1. *M. calcarea*
21. Spores globose not filling the 3-lobed sporang., diameter 16–20μ ..... 23. *M. notabilis*
21. Spores cylindric, 48–56μ x 64–78μ ..... 22a. *M. laetevirens varians*
22. Spore wall smooth 23
22. Spore wall punctate, scrobiculate, or verrucose 28
23. Diameter veg. cells more than 12μ 24
23. Diameter veg. cells less than 10μ 25
24. Spores brownish violet with angles produced ..... 37. *M. capucina*
24. Spores quadrate regular, with sides 22–28μ long ..... 26. *M. fragilis*
25. Angles of zygospores rounded or undulate truncate 26
25. Angles of zygospores retuse; margins concave ..... 25. *M. viridis*
25. Angles of zygospores produced 27
26. Diameter veg. cells 3.5–4.5μ ..... 24. *M. elegantula*
26. Diameter veg. cells 8–9μ ..... 27. *M. virescens*
26. Diameter veg. cells 11.5–13.5μ ..... 28. *M. paludosa*
27. Diameter veg. cells 4–5μ, zyg. irreg., processes truncate ..... 31. *M. americana*
27. Diameter veg. cells 5–6μ, zyg. rounded, processes short rounded ..... 34. *M. corniculata*
27. Diameter veg. cells 6–8μ, zyg. wall very thick, processes long rounded ..... 35. *M. uberosperma*
28. Spore wall punctate 29
28. Spore with concave sides, wall verrucose ..... 33. *M. gracillima*
28. Spore with convex sides, wall minutely scrobiculate ..... 39. *M. tumidula*
29. Diameter veg. cells 13μ or less 30
29. Diameter veg. cells more than 13μ 32
30. Zygospores quadrate 31
30. Zygospores cruciate quadrate, diameter veg. cells 8–10μ ..... 40. *M. punctata*
30. Zygospores quadrate with angles produced ..... 42. *M. producta*
31. Diameter veg. cells 4–5μ, reproduction mostly by aplanospores ..... 29. *M. boodlei*
31. Diameter veg. cells 8–13μ, sides of zygospores 28–40μ ..... 32. *M. quadrangulata*
32. Zygospores ovoid-globose 38–46μ x 38–48μ ..... 43. *M. aspera*
32. Zygospores irregular quadrate, with long processes ..... 38. *M. irregularis*
33. Diameter veg. cells 4–5μ, spores oblique ellipsoid 35
33. Diameter veg. cells 6–7μ, spores oblique globose ..... 36. *M. tropica*
33. Diameter veg. cells 8–13μ 34
33. Diameter veg. cells 13–15μ, spores oblique ellipsoid, punctate ..... 45. *M. mayori*
34. Aplanospores globose to ovoid smooth, diam. 17–21μ ..... 1. *M. calcarea*
34. Aplanospores ellipsoid with retuse ends, punctate ..... 41. *M. prona*
34. Aplanospores ovoid to ellipsoid, 12–24μ x 16–29μ, smooth ..... 44. *M. ventricosa*
35. Spore wall smooth ..... 30. *M. tenerrima*
35. Spore wall punctate ..... 29. *M. boodlei*

1. *M. calcarea* (Cleve) Wittrock, 1872.

Bih. till K. Sv. Vet. Akad. Handl. I, No. 1; *Sphaerospermum calcareum* Cleve, 1868; *Mougeotia sphaerica* Gay, Essai d'une Monographie locale des Conjuguees. Montpellier, 1884; *Gonatonema sphaerospora* Borge, Arkiv. for Botanik, 1:282. 1903.

Vegetative cells 8–14μ x 40–280μ, chromatophore .5–.7 the cell length, cells elongating and becoming geniculate before spore formation; zygospores globose, 25–30μ in diameter or angular-globose, 22–28μ x 30–50μ, wholly in the tube, or extending into one or both gametangia, spore wall smooth, colorless; aplanospores globose, lateral to the sporogenous cell or extending into the sporogenous cell, 17–21μ in diameter, or rarely trapezoid ovoid dividing the sporogenous cell, 15–20μ x 20–28μ.

United States: Illinois, Michigan, Mississippi, Ohio. Sweden, France, Greenland, North Africa, Brazil, British Columbia.

(Plate I, Figs. 9–14).

This is the most variable of all the described species and shows all of the types of spore formation which led the early students of the group to postulate several distinct genera. In Mississippi, Illinois and Brazil only the aplanospores have been found.

a-var. *bicalyptrata* (Wiitrock) *comb. nov.*

W. & N. Alg. Exsic. No. 741; Bot. Not. 1886, p. 135.

Vegetative cells 10–12μ x 30–110μ; zygospores with thickened end walls adjoining the gametangia, sometimes completely closing the gametangia.

United States: Michigan. British Columbia, Sweden.

(Plate I, Fig. 8).

2. *M. parvula* Hassall, 1843.

Ann. and Mag. Nat. Hist. 11:434.

Vegetative cells 6–12μ x 30–140μ chromatophore usually occupying two-thirds of the cell with 4–6 pyrenoids, sporangia adjoined by two cells; zygospores formed wholly in the conjugating tube, globose, 13–24μ in diameter, wall thick, smooth, brown; aplanospores obliquely ovoid, 16–20μ x 20–24μ.

United States: Massachusetts, Rhode Island, Michigan, Ohio, North Carolina. British Isles, Germany, Austria, Switzerland, France, Sweden, Norway, Belgium, Finland, Czecho-Slovakia, Brazil, Japan.

(Plate I, Figs. 1–3).

a-var. *angusta* (Hass.) Kirchner 1878.

Alg. Schless, p. 128. *Mesocarpus angustus* Hass. 1845; *Sphaerocarpus angustus* Hass., 1843a.

Vegetative cells 5–6μ x 30–95μ, zygospore diameter 7–8μ.

United States: South Carolina. British Isles, Germany, Austria, Belgium, Czecho-Slovakia.

b-var. *ellipsoideis* W. & G. S. West, 1907.
Ann. Roy. Bot. Gard., Calcutta, 6, part 2.

Vegetative cells as in the type, zygospores ellipsoid.
Burma.
(Plate I, Figs. 4–5).

3. *M. recurva* (Hass.) De Toni, 1889.
Sylloge Algarum, p. 714. *Mesocarpus recurvus* Hassall, 1845; *Sphaerocarpus recurvus* Hassall, 1843a.

Vegetative cells 12–18μ x 50–180μ, sporangia adjoined by 2 cells; zygospores globose, 23–33μ; median spore wall smooth, brown; aplanospores globose (diam. 24μ) at the angles of geniculate cells, or cylindric ovoid 14μ x 34μ in straight cells.

United States: Douglas Lake, Michigan. British Isles, Germany, Australia, South America.
(Plate I, Figs. 6–7).

4. *M. nummuloides* (Hassall) De Toni, 1889.
Sylloge Alg., p. 713, P. B. A. 714.

Vegetative cells 8–16μ x 32–160μ, sporangia adjoined by 2 cells; zygospores globose to ovoid 17–37μ in diameter; aplanospores ovoid within the angled sporogenous cell; median spore wall brown, scrobiculate.

United States: Maine, Massachusetts, New Jersey, North Carolina, Ohio. British Isles, Belgium, Luxemburg, Germany, Sweden, Czecho-Slovakia, Finland.
(Plate I, Figs. 15–16).

5. *M. scalaris* Hassall, 1842.
Ann. and Mag. Nat. Hist., 10:34.

Vegetative cells 20–34μ x 40–180μ; fertile cells straight or slightly curved; sporangia adjoined by 2 cells; zygospores ovoid to globose 30–38μ–(40μ) in diameter; median wall smooth, yellow-brown, occupying the conjugating tube.

United States: South Carolina, Georgia, Illinois, New Jersey, Pennsylvania, Florida, Iowa, Ohio. Great Britain, Sweden, Belgium, France, Russia, Italy, Germany, Czecho-Slovakia, Queensland, New Caledonia, Japan, Luxemburg.
(Plate II, Figs. 25–27).

a-var. *macrospora* Hirn. 1895.
Acta Soc. pro Fauna et Flora Fennica 11, No. 10.

Vegetative cells 25–28μ x 60–140μ; zygospores ovoid larger than the type, 40–48μ x 43–50μ.

United States: Michigan. Finland.

6. *M. megaspora* Wittrock, 1872.
Bih. till K. Sv. Vet. Acad. Handl. 1, No. I.

Vegetative cells 17–19.5μ x 170–380μ, sporangia adjoined by 2 cells; zygospore globose to ovoid, 41–44μ x 45.5–48μ; median spore wall brown, irregularly scrobiculate.
Sweden.
(Plate II, Fig. 23).

7. *M. gotlandica* (Cleve) Wittrock, 1872.
Bih. till K. Sv. Vet. Akad. Handl. 1, No. 1.

Vegetative cells about 22μ x 75–150μ; sporangium adjoined by 2 cells; zygospores globose, about 30μ in diameter; median spore wall yellow-brown, wrinkled.
Sweden, Luxemburg.
(Plate II, Fig. 24).

8. *M. pulchella* Wittrock, 1871.
Hedwigia, p. 88.

Vegetative cells 24–29μ x 48–150μ; sporangium adjoined by 2 cells; zygospores ovoid to ellipsoid with ends more or less flattened, 28–35μ x 40–50μ; median spore wall yellow-brown, punctate.
United States: Douglas Lake, Michigan. Sweden, Germany.
(Plate IV, Fig. 53).

9. *M. robusta* (De Bary) Wittrock, 1885.
W. & N. Alg. Exsicc., No. 651.

Vegetative cells 25–33μ x 75–260μ, chromatophores with many irregularly distributed pyrenoids, zygospores adjoined by 2 cells, ovoid to subglobose, 35–41μ x 47–54μ, wall scrobiculate, brown.
United States: Iowa, Ohio, Massachusetts, New Jersey, Illinois. Germany, Japan.
(Plate III, Figs. 39–41).

A rather common species in the eastern United States. Both the species and variety have occasional filaments with two parallel chromatophores in each cell, or a single chromatophore more or less divided toward the ends. Distinguished from *M. gotlandica* (Cleve) Wittr. by its larger dimensions, and the color and marking of the spore wall; from *M. pulchella* Wittr. by the reddish brown color of the spores.

a-var. *biornata* Wittrock, 1884.
W. & N. Alg. Exsicc., No. 615; Bot. No. t 1884, p. 126.

Vegetative cells 22–30μ x 25–240μ; zygospores 30–38μ x 42–50μ, outer wall inwardly verrucose, fitting the scrobiculations of the median wall.
United States: Illinois, Iowa, Ohio, Michigan. Sweden, Ceylon.

The structure of the outer wall may be readily demonstrated by crushing a spore and adding a drop of potassium hydroxide or some other reagent that will cause the wall to swell.

10. *M. sphaerocarpa* Wolle, 1887.

Freshwater algæ, p. 227; *M. minnesotensis* Wolle, 1887; *M. divaricata* Wolle, 1887.

Vegetative cells 19–24μ x 60–120μ (–240μ), gametangia curved, usually 4–6 pyrenoids; zygospore in the greatly enlarged conjugating tube, or extending into the gametangia, ovoid to subglobose, 40–45μ in diameter or ovoid 36–40μ x 40–55μ, wall smooth, brown; aplanospores ovoid to obliquely ovoid 24–30μ x 35–50μ.

United States: Minnesota, New Jersey, Pennsylvania, Illinois, Iowa, Ohio, California, Florida.

(Plate III, Figs. 28–33).

var. *varians* var. nov.

Vegetative cells 24–28μ x 100–240μ, aplanospores ovoid 34–36μ x 38–42μ, zygospores frequently ovoid 35–44μ x 44–60μ, touching one or both of the outer walls of the gametangia.

Manila, Philippine Islands. (Collected by Walter R. Shaw).

(Plate III, Figs. 34–35).

This new variety superficially resembles *Debarya africana* G. S. West, but differs in the thickening of the end walls of the gametangia and in the fact that only a part of the contents of the conjugating cells enter the zygospore.

11. *M. subcrassa* G. S. West, 1906.

Jour. Linn. Soc. Bot., 39:50.

Vegetative cells 41.5–43μ x 240–280μ, chromatophore with 15–24 pyrenoids deposited irregularly; conjugating cells straight or slightly curved; zygospores globose between two undivided gametangia, 40–41μ in diameter, outer wall smooth and indistinctly lamellate. Sporangial wall thicker at the ends of the tube.

Victoria, Australia.

(Plate IV, Fig. 54).

12. *M. crassa* (Wolle) De Toni, 1889.

Sylloge algarum, p. 716; *Mesocarpus crassus* Wolle, Bull.Torrey Bot. Club, 12:127, 1885.

Vegetative cells about 50μ x 200–500μ spores globose, about 65μ in diameter, filling the tube, not extending into the gametangia, outer wall smooth.

United States: Florida.

(Plate III, Fig. 38).

The large size of the vegetative cells distinguishes this from all other described species. I have found vegetative filaments of these dimensions in Illinois, Mississippi and Alabama, but the fruiting record is based on Wolle's collection and description.

13. *M. macrospora* (Wolle) De Toni, 1889.
Sylloge Algarum, p. 716; *Mesocarpus macrosporus* Wolle, 1887.

Vegetative cells about 30μ x 180–300μ; gametangia slightly recurved; sporangia adjoined by 2 cells; zygospores globose, 55–60μ in diameter, outer wall smooth, fully occupying the greatly enlarged tube.
United States: Pennsylvania, New Hampshire.
(Plate III, Fig. 36).

Distinguished from *M. sphaerocarpa* Wolle and *M. crassa* (Wolle) De Toni, which it resembles, by the differences in dimensions of both vegetative cells and spores. The species seems not to have been found since Wolle's records and his specimens are lost.

14. *M. genuflexa* (Dillwyn) Agardh., 1824.
Systema Alg., p. 83; *Mesocarpus pleurocarpus* DeBary, *Mougeotia mirabilis* (A. Br.) Wittr.

Vegetative cells 25–38μ x 50–225μ, often geniculate and attached to other similar cells forming extensive nets, sometimes with rhizoidal branches; conjugation lateral, less frequently scalariform; sporangia adjoined by 2 cells; zygospores quadrately ovoid to globose, 30–40μ in diameter; wall smooth, brown.
United States: Maine, Massachusetts, Connecticut, New Jersey, Pennsylvania, Michigan, Minnesota, Illinois, Iowa, Ohio, Louisiana. British Isles, Sweden, Denmark, Belgium, Luxemburg, Germany, Russia, Austria, France, Czecho-Slovakia.
(Plate IV, Figs. 43–44).

a-var. *gracilis* Reinsch, 1867.
Die Alg. Flora von Franken, p. 215. P. B. A. 312.

Vegetative cells 15–24μ in diameter; zygospores 24–30μ in diameter; otherwise like the type.
United States: Illinois. Germany, Czecho-Slovakia, Java.
(Plate IV, Fig. 45).

15. *M. depressa* (Hassall) Wittrock, 1880.
Skandinaviens vaxter, part 4; *Mesocarpus depressus* Hass.. 1845; *Sphaerocarpus depressus* Hass., 1843a.

Vegetative cells 7–12μ x 35–144μ; sporangia adjoined by 2 cells; conjugation lateral and scalariform; zygospores compressed ellipsoid 12–14μ x 28–32μ, longer axis parallel to the filaments, median wall punctate, brown.
United States: Gainesville, Florida. British Isles, Germany, Sweden, Luxemburg.
(Plate II, Fig. 20).

Evidently closely related to *M. parvula* Hass., from which it differs in the form of the spore and spore wall.

16. *M. ovalis* (Hassall) Nordstedt, 1886.
W. & N. Alg. Exsicc., No. 742; Botaniska Nortiser, 1886, p. 136.

Vegetative cells 11–14μ x 110–140μ; sporangia adjoined by two cells; zygospore compressed ovoid to subglobose 26–36μ x 29–38μ; median spore wall pitted.
British Isles, Italy, Germany.
(Plate III, Fig. 37).

17. *M. gelatinosa* Wittrock, 1889.
W. & N. Alg. Exsicc. No. 957, fasc. 21, pp. 26-27.

Vegetative cells 13–18μ x 120–180μ; sporangium adjoined by 2 cells; zygospores compressed ovoid, 38–47μ x 28–39μ, not including the outer pectic layer, which may be 7–10μ in thickness; median spore wall brown, smooth.
British Isles, Sweden, Finland.
(Plate II, Fig. 17).

In this and the three following species the pectic layer is quite transparent and is visible largely through the accumulation of clay particles on its exterior surface. At maturity the pectic layer may be absent from some of the spores, apparently having gone into solution.

18. *M. cyanea* sp. nov.

Vegetative cells (14–) 16–18μ (–20μ) x 160–200μ, chromatophore occupying one-third to one-half of the cell, with 4 to 10 pyrenoids in a straight line; zygospores compressed spherical 30–40μ x 38–48μ with the longer axis parallel to the filaments; aplanospores spheroidal, laterally placed in the sporogenous cell, 30–32μ in diameter; both kinds of spores surrounded at maturity with a transparent pectic layer 4μ to 8μ thick; spore wall finely punctate, blue.
United States: Douglas Lake, Michigan. (Collected by G. E. Nichols).
(Plate II, Figs. 21–22).

19. *M. maltae* Skuja, 1926.
Acta Horti Botanici, Univ. Latviensis, 1:109. Fig. 1 and Pl. I, Fig. 1.

Vegetative cells 17–22μ x 60–120 (–200)μ; chromatophore nearly as long as the cell with 4 to 8 pyrenoids; conjugating cells slightly incurved; zygospores globose (30)–32–35–(40)μ in diameter, spore wall smooth, blue, surrounded by a gelatinous layer 4 to 6μ in diameter.
Usma Lake, Latvia.
(Plate II, Fig. 18).

20. *M. victoriensis* G. S. West, 1909.
Jour. Linn. Soc. Bot., 39:51.

Vegetative cells 11–12μ x 100–160μ; chromatophores with two to seven, usually 5 or 6, pyrenoids arranged in a single slightly irregular

series; conjugating cells recurved; zygospores globose contained within the tube; median spore wall smooth; surrounding the sporangium a layer of pectic material develops which extends even beyond the outer sides of the gametangia. Diameter of the spores 21–24μ; diameter including the pectic coat, 60–63μ.

Victoria, Australia.

(Plate II, Fig. 19).

21. *M. angolensis* W & G. S. West, 1897.

African Freshwater Algæ, Jour. Bot. 35:39.

Vegetative cells 25–29μ x 100–145μ, chromatophores with 4 to 6 very small pyrenoids irregularly disposed; zygospores short cylindric with concave sides, 19–21μ in diameter; wall smooth; gametangia slightly curved.

Angola, Africa.

(Plate IV, Fig. 42).

The chromatophore has fewer pyrenoids and the zygotes are smaller than in *M. laetevirens* (A. Br.) Wittr.

22. *M. laetevirens* (Braun) Wittrock, 1877.

W. & N. Alg. Exsicc., No. 58; Bot. Notiser, 1877, p. 23.

Vegetative cells 22–40μ x 65–350μ, many pyrenoids irregularly disposed conjugating cells geniculate; sporangia adjoined by 2 cells; zygospores contained in the tube, outer wall short cylindric, 36–47μ x 45–72μ with concave sides; aplanospores ovoid or obliquely ovoid; median wall smooth, yellow-brown.

United States: Ohio, New Jersey, Long Island, N. Y., Michigan, New Hampshire, Massachusetts, Wisconsin, North Carolina. Sweden, Germany, Luxemburg, Czecho-Slovakia, Finland, Queensland, Paraguay, Outer Mongolia, Brazil.

(Plate IV, Figs. 46–50).

a.-var. *varians* Wittrock, 1886.

W. & N. Alg. Exsicc., No. 740; Bot. Notiser, 1886, p. 135.

Zygospores extending into or across the gametangia, sporangia adjoined by 2, 3, or 4 cells; spores 48–56μ x 64–78μ.

Sweden, Germany, Czecho-Slovakia.

(Plate IV, Figs. 51–52).

23. *M. notabilis* Hassall, 1840.

Ann. and Mag. Nat. Hist., 10:46; *Plagiospermum tenue* Cleve, 1868; *Mougeotia tenuis* (Cleve) Wittrock, 1872; *Mougeotia Transeaui* Collins, 1912.

Vegetative cells 10–18μ x 50–250μ, usually only one gametangium is divided by the sporangium which is consequently triangular ovoid; zygospores not completely filling the sporangia, more or less ovoid to subglobose, 24–28μ x 26–36μ; aplanospores obliquely ovoid to trapezoid 16–20μ x 25–30μ, sporogenous cell geniculate or straight; spore wall smooth.

United States: Illinois, Iowa, Ohio, Pennsylvania, New Jersey, Florida. Sweden, British Isles.

(Plate V, Figs. 55–59).

There is no doubt about the identity of the species figured by Hassall. It contained only aplanospores and is quite similar to immature aplanosporic material found in Illinois. Collins' species was described from the first material of the kind which I found in Illinois. Subsequently an abundance of material was found which established the identity of the three species. I have seen material upon which Wolle based his *Mougeotia tenuis* var. crassa, and it is typical of *M. notabilis*.

24. *M. elegantula* Wittrock, 1872.
Om Gotlands, etc., p. 40.

Vegetative cells 3.5–4.5μ x 50–135μ; chromatophores with 4–8 pyrenoids; conjugating cells geniculate, sporangium adjoined by 4 cells; zygospores cruciate-quadrate, 18–24μ with smooth, hyaline walls, the corners rounded.

United States: Massachusetts, Illinois, Michigan. Sweden, West Indies.

(Plate VI, Figs. 84–87).

25. *M. viridis* (Kuetz.) Wittrock, 1872.
Om Gotlands, etc., p. 39.

Vegetative cells 6–8μ x 24–80μ; chromatophores occupying most of the cell with 4–6 pyrenoids; zygospores adjoined by 4 cells, quadrate with concave sides, and retuse angles, 22–32μ on the side; aplanospores oblique ellipsoid, 14–16μ x 30–36μ; median spore wall smooth, colorless.

United States: New Jersey, Wisconsin, Illinois, Florida. British Isles, Sweden, Germany, Czecho-Slovakia, Austria, Hungary, France, Belgium, Russia, Finland, Luxemburg.

(Plate VII, Figs. 97–98).

26. *M. fragilis* (Zeller) De Toni, 1873.
Hedwigia, p. 174.

Vegetative cells 17–22μ x 85–200μ, zygospores quadrangular with sides 22–28μ long. Spore wall smooth.

Pegu, Burma.

27. *M. virescens* (Hassall) Borge, 1923.
Zygnemales in Pascher's Susswasserflora, 9:43; *Staurocarpus virescens* Hassall, 1845.

Vegetative cells 8–9μ x 30–110μ, sporangia adjoined by 4 cells; zygospores quadrate, with concave sides, 29–34.5μ; wall colorless, smooth, with rounded corners.

British Isles.

(Plate VII, Fig. 104).

27. *M. paludosa* G. S. West, 1899.
Algalflora of Cambridgeshire. Jour. Bot. 37:108, pl. 395, figs. 4–6.

Vegetative cells 11.5–13.5μ x 70–185μ, chromatophores short, occupying about one-third the length of the cell with about 5 pyrenoids; fertile cells recurved; zygospores ovoid to quadrangular ovoid, adjoined by 4 cells; angles undulate truncate; outer wall of zygospore thick, colorless; spores 32–38μ x 44–49μ.
Cambridgeshire, England.
(Plate V, Figs. 73–75).

Distinguished from all other species by the thick colorless spore wall with its undulate truncate angles. Probably nearest *M. capucina* (Bory) Agardh from which it is readily distinguished by its smaller dimensions and absence of the violet color.

29. *M. Boodlei* (W. & G. S. West) Collins, 1912.
Tufts College Studies, 3:69.

Vegetative cells 4–5μ x 25–225μ; chromatophore .5–8 the length of the cell, with 4–6 pyrenoids; zygospores quadrate, 15–18μ x 15–23μ; corners somewhat rounded; aplanospores ellipsoid, 12–15μ x 23–25μ, projecting slightly on the convex side of the slightly curved sporangia; spore wall punctate, yellow-brown.
United States: Illinois. British Isles.
(Plate VI, Figs. 78–80).

30. *M. tenerrima* G. S. West, 1914.
Mem. Soc. neuchateloise Sci. Nat. 5:1028.

Vegetative cells 4.5μ x 110–135μ, chromatophores with 6 pyrenoids in one series; zygospores unknown; aplanospores oblique-ellipsoid, 12–13μ x 24–25μ, ends slightly mamillate, wall smooth.
South America: Columbia.
(Plate VI, Figs. 81–83).

31. *M. americana* Transeau, 1918.
Tech. Pub. No. 9, N. Y. State Coll. of Forestry, p. 237.

Vegetative cells 4–5μ x 40–120μ; conjugating cells slightly or strongly geniculate; zygospore adjoined by four walls, irregularly quadrate with concave or convex sides; angles produced and truncate, the space between the zygospore and the sporangium walls being filled with pectic material, 13–24μ x 18–32μ, wall smooth, transparent; aplanospores obliquely elliptical, ends truncate at the middle of very long genuflexed vegetative cells, 10–14μ x 20–26μ.
Oneida Lake, N. Y.; Douglas Lake, Mich.
(Plate VI, Figs. 88–93).

32. *M. quadrangulata* Hassall 1843.
Ann. and Mag. of Nat. Hist. 11:434. DeBary, 1858, Sranrospermum quadration.

Vegetative cells 8–13μ x 50–140μ; with 8 to 16 pyrenoids in a line, conjugating cells geniculate, sporangia adjoined by 4 cells; zygospores

quadrate with straight sides and truncate corners or rarely with angles retuse, 28–40μ on a side, with colorless, punctate wall; aplanospores obliquely ovoid, 20–21μ x 36–44μ.

United States: Illinois, Ohio, Michigan, Massachusetts, New Jersey, North Carolina, Florida. British Isles, Belgium, Germany, Russia, France, Czecho-Slovakia, Sweden, Austria, Poland.

(Plate V, Figs. 70–72).

33. *M. gracillima* (Hassall) Wittrock, 1872.
Om. Gotlands, etc., p. 40.

Vegetative cells 5–7μ x 55–140μ; sporangia adjoined by 4 cells (rarely 3); zygospore quadrate, with deeply concave sides, 20–25μ x 20–28μ, angles retuse; wall minutely verrucose.

United States: Illinois, New York, Massachusetts, Michigan. British Isles, Sweden, Luxemburg, Germany, Czecho-Slovakia, France.

(Plate VI, Figs. 95–96).

34. *M. corniculata* Hansgirg, 1886.
Oesterr. Botan. Zeitschr., No. 10.

Vegetative cells 5–6μ x 30–180μ; sporangia adjoined by 4 cells; zygospores quadrately ovoid, 22–26μ x 22–26μ; median spore wall yellow-brown, smooth, thickened, forming rounded processes at the corners.

Czecho-Slovakia.

(Plate VI, Fig. 94).

35. *M. uberosperma* W. & G. S. West, 1897.
Welwitsch's African Freshwater Algæ. Jour. Bot. 35:37.

Vegetative cells 6–8μ x 24–64μ, fertile cells recurved; zygo sporangia dividing both gametangia; zygospores angular globose (4–6 angles), wall very thick and lamellate, colorless, with corners extended into 4 solid unequal processes which project into the gametangia; diameter of the zygospores 21–27μ; processes 3–18μ long. Aplanospore 20μ x 30μ with two processes.

Angola and Kentani, Africa.

(Plate VII, Figs. 102–103).

36. *M. tropica* (W. & G. S. West, 1916.
Algæ, p. 337; Annals of Botany 12:39, Pl. 4; *Gonatonema tropicum*, Jour. Bot. 35:38, 1897.

Vegetative cells 6–7μ x 36–56μ with two pyrenoids in the chromatophore; zygospores unknown; aplanospores obliquely globose with projecting mamillate solid processes, median wall yellow-brown, scrobiculate, 27–28μ x 27–29μ, with the processes 42–46μ in length.

Angola, Africa.

(Plate VII, Fig. 112).

37. *M. capucina* (Bory) Agardh., 1824.
Systema algarum, p. 84; *Staurospermum capucinum* De Bary, 1858, p. 81.

Vegetative filaments usually violet colored, cells 14–21μ x 70–280μ (–340μ); chromatophore with 4–6 (–8) pyrenoids, frequently rod-shaped, occupying one-third to one-fourth the length of the cell, or ribbon-like containing 12–16 chromatophores in a line and extending three-fourths the length of the cell; sporangium walls formed at a distance (5–52μ) from the zygospore, the intervening space being filled with pecto-cellulose compounds; sporangium dividing both gametangia; zygospores irregularly quadrangular with concave sides 50–70μ x 60–100μ, wall violet-brown, thick especially at the angles, smooth; aplanospores not uncommon 20–36μ x 45–70μ (–80μ) with more or less thickened ends.

United States: Long Island, N. Y.; North Carolina, Florida, Alabama. British Isles, France, Sweden, Belgium, Switzerland, Italy, Brazil, New Zealand.

(Plate V, Figs. 62–69).

38. *M. irregularis* W. & G. S. West, 1897.
Welwitsch's African Freshwater Algæ. Jour. Bot. 35:38.

Vegetative cells 13.5–15μ x 70–90μ; conjugating cells more or less recurved; sporangium dividing both gametangia; zygospores irregularly quadrate or trapezoid with concave sides and thick walls; angles with horn-like processes of varying length with rounded ends; median spore wall thick, yellow to yellow brown, punctate; extreme length of zygospore including the processes 38–63μ, extreme width, 42–48μ.

Angola, Africa.

(Plate V, Figs. 60–61).

39. *M. tumidula* Transeau, 1914.
Amer. Jour. Bot. 1:297.

Vegetative cells 6–8.5μ x 70–120μ, chromatophore with 4 to 8 pyrenoids, sporangia adjoined by 4 cells; zygospores quadrate, somewhat tumid 22–26μ x 26–30μ, angles retuse, walls colorless, minutely but distinctly scrobiculate; aplanospores obliquely ellipsoid 12–14μ x 28–32μ, with retuse ends and scrobiculate wall.

United States: Illinois, Iowa.

(Plate VII, Fig. 105).

40. *M. punctata* Wittrock, 1867.
Algolgiska studier, I. Upsala.

Vegetative cells 8–10μ x 50–120μ; sporangia adjoined by four cells; zygospores quadrate, 30–38μ on a side, 18–20μ thick; sides concave with obtuse angles, outer wall crenulate, inner nearly smooth.

Upland, Sweden.

(Plate VII, Figs. 99–101).

41. *M. prona* sp. nov.

Vegetative cells 8–12μ x 60–140μ (–280μ) with 6 to 12 pyrenoids; aplanospores 20–24μ x 40–52μ (–60μ), sporangium obliquely ellipsoid

with ends produced and truncate, spore wall faintly yellow and finely punctate with retuse ends.

United States: Long Island, N. Y.

(Plate VII, Figs. 109–111).

This species occurred abundantly in 1924 in a rivulet below a roadside spring on the south side of High Hill. It produced aplanospores throughout July and early August. Distinguished from *M. tumidula* Transeau by its larger size and yellowish walls; from *M. quadrangulata* (Hass) Wittr. by the retuse angles and yellowish walls. Evidently near *M. punctata* Wittr., but no zygospores, which might have connected it with that species were found.

42. *M. producta* G. S. West, 1907.

Freshwater Algæ from Burma. Annals Royal Bot. Gard., Calcutta 6,part 2.

Vegetative cells 7–8μ x 84–160μ; zygosporangia adjoined by 4 cells; zygospores quadrate, with concave or slightly convex sides, angles produced and truncate, 29–37μ on a side; aplanospores obliquely ellipsoid with ends produced and with a similar thickening near the ends, 14–18μ x 30–40μ; median spore wall punctate, colorless.

Burma.

(Plate VII, Figs. 113–114).

43. *M. aspera* Voronikhin.

Notulæ syst. ex Inst. Crypt. Horti bot. Petropolitani, 2:192. Petrograd, 1923.

Vegetative cells 13–16.5μ x 78–112μ; sporangium adjoined by 4 cells; zygospores globose, 36–46μ in diameter, rarely ovoid 46μ x 66μ; median spore wall pale brown, punctate.

Tiflis, Georgia (Asia Minor).

44. *M. ventricosa* (Wittrock) Collins, 1912.

Tufts College Studies, 3:69.

Vegetative cells 5–9μ x 100–140μ; zygospores unknown; aplanospores obliquely ellipsoid to subglobose, 12–24μ x 16–29μ; median spore wall smooth, yellow-brown.

United States: Pennsylvania, California, Michigan. Europe.

(Plate VII, Figs. 106–108).

45. *M. mayori* G. S. West, 1914.

Mem. Soc. Neuchateloise d. Sci. Nat. 5, 1027.

Vegetative cells 13–15μ x 235–315μ with 11 to 14 pyrenoids; aplanospores 24–26μ x 34–38μ, obliquely ellipsoid with truncate ends, median spore wall yellow, punctate.

Central Andes of Columbia, South America.

(Plate V, Figs. 76–77).

BIBLIOGRAPHY

1824. Agardh, C. A. Systema Algarum, p. XXVI. Lund.
1913. Borge, O. Zygnemales. Die Susswasserflora Deutschlands, Oesterreichs und der Schweiz. Vol. 9. Jena.
1868. Cleve, P. T. Forsok till en Monografi ofver de svenska arterna af Algfamiljen Zygnemaceæ Nov. Act. Reg. Soc. Sc. Upsala, Ser. 3, Vol. 6.
1909. Collins, F. C. Green Algæ of North America. Tufts College Studies, 2:122.
1912. Collins, F. C. Supplement to Green Algæ of North America. Tufts College Studies, 3:69.
1918. Collins, F. C. Second Supplement to Green Algæ of North America. Tufts College Studies, 4:1.
1858. De Bary, A. Untersuchungen uber die Familie der Conjugaten. Leipsig.
1889. De Toni, G. B. Sylloge Algarum 1: 2; 711–726. Padua.
1842. Hassall, A. H. Observations on the genera Zygnema, Tyndaridea, and Mougeotia. Ann. and Mag. Nat. Hist., 10:34.
1843. Hassall, A. H. Descriptions of British Freshwater Confervæ. Ann. and Mag. Nat. Hist., 11:428.
1843a. Hassall, A. H. Observations on the genus Mougeotia. Ann. and Mag. Nat. Hist., 12: 180, Pl. VII.
1845. Hassall, A. H. History of the British Freshwater Algæ. London. Mougeotia 1:166–179; 2: Pl. XL–XLIX.
1895. Hirn, K. E. Die Finlandischen Zygnemacean. Acta. Soc. pro Fauna et Flora Fennica. 11, No. 10.
1878. Kirchner, O. Algen, in Cohn, Kryptogamenflora von Schlesien, p. 178. Breslau.
1855. Kuetzing, F. T. Tabulæ Phycologicæ. Vol. 5. Nordhausen.
1926. Skuja, H. Zwei neue Zygnemaceen. Acta Horti. Bot. Univ. Latviensis 1:109.
1914. Transeau, E. N. New Species of Green Algæ. Amer. Jour. Bot., 1:297.
1918. Transeau, E. N. A New Species and a New Variety of Algæ from Oneida Lake, New York. Tech. Pub. No. 9, p. 237, N. Y. State Coll. of Forestry.
1925. Transeau, E. N. The Genus Debarya. Ohio Jour. Sci. 25:193. 1925
1803. Vaucher, J. P. Histoire des Conferves d'eau douce. Geneva. Mougeotia, page 79, Pl. 8.
1923. Voronikhin, N. N. Notulæ syst. Inst. Crypt. Horti Bot. Petropolitani, 2:192.
1909. West, G. S. Algæ of the Yan Yean Reservoir, Victoria. Jour. Linn. Soc. Bot., 39: 1–88.
1914. West, G. S. Freshwater Algæ of Columbia. Mem. Soc. Neuchateloise Sci. Nat. 5: 1013–1051.
1916. West, G. S. Algæ. Cambridge Botanical Handbooks. 1: 328–343.
1897. West, W. & G. S. Welwitsch's African Freshwater Algæ. Jour. Bot. 35:33. Mougeotia 37–39.
1898. West, W. & G. S. Observations on the Conjugatæ. Annals of Botany 12: 29–58.
1907. West, W. & G. S. Freshwater Algæ from Burma. Ann. Roy. Bot. Gard. Calcutta, 6: Part 2.
1867. Wittrock, W. B. Algologiska Studier, I. Upsala.
1871. Wittrock, W. B. Beitrag zur Kenntniss der Zygnemaceen und Mesocarpaceen. Cfr Hedwigia. 1871 p. 88.
1872. Wittrock, W. B. Om Gotlands och Oelands Sotvattenalger. Bih. Kgl. Svensk. Vet.-Akad. Handl. 1: 1; 3–72. Pl. 1–4.
1878. Wittrock, W. B. Spore formation of the Mesocarpeæ. Bih. Kgl. Svensk. Vet.-Akad. Handl. 5:1.
1880. Wittrock, W. B. Points-forteckning ofver Skandinaviens vaxter. Part 4. Lund.
1885. Wolle, F. Freshwater Algæ, X. Bull. Torr. Bot. Club. 12:125.
1887. Wolle, F. Freshwater Algæ of the United States. Bethlehem.
1873. Zeller. Algen gesa mmelt von S. Kurz in Arracan und British Burma. Hedwigia 1873, p. 168, 189.

EXPLANATION OF PLATES.

Plate I.

Figs. 1–2. *Mougeotia parvula*—Finland, Nylandia. Coll. C. Cedercreutz. June 21, 1921.

Fig. 3. *M. parvula*—Aplanospore from Burgaw, North Carolina. Coll. D. B. Anderson, March 30, 1926.

Figs. 4–5. *M. parvula* var. *ellipsoideis*—After W. & G. West, 1907. Burma.

Figs. 6–7. *M. recurva*—Douglas Lake region, Michigan. Coll. G. E. Nichols. August 10, 1925.

Fig. 8. *M. calcarea* var. *bicalyptrata*—British Columbia. Coll. W. R. Taylor. 1921.

Fig. 9. *M. calcarea*—Aplanospore, Casey, Illinois, April 22, 1911.

Fig. 10. *M. calcarea*—Zygospores drawn to scale after Wittrock, 1878.

Figs. 11, 13. *M. calcarea*—Zygospores, Carp Lake, Michigan, August 9, 1915.

Figs. 12, 14. *M. calcarea*—Aplanospores, West Point, Mississippi, April 16, 1925.

Fig. 15. *M. nummuloides*—Douglas Lake region, Michigan, July 28, 1924 (G. E. Nichols).

Fig. 16. *M. nummuloides*—Aplanospores, Burgaw, North Carolina. Coll. D. B. Anderson, March 30, 1926.

Plate II.

Fig. 17. *Mougeotia gelatinosa*—After Wittrock. Bot. Not. 1889, p. 163.

Fig. 18. *M. maltæ*—After H. Skuja, 1926.

Fig. 19. *M. victoriensis*—After G. S. West, 1909.

Fig. 20. *M. depressa*—After Kutzing, 1855, Vol. 5, Pl. 7.

Fig. 21. *M. cyanea*—Douglas Lake region, Michigan, July 28, 1924. G. E. Nichols. The gelatinous pectic layer of the lower zygospore has disappeared.

Fig. 22. *M. cyanea*—Douglas Lake region, Michigan, showing zygospore and aplanospore.

Fig. 23. *M. megaspora*—After Wittrock, 1872, and Coll. O. Borge, Ave, Sweden, July, 1886.

Fig. 24. *M. gotlandica*—After Cleve, 1868.

Figs. 25–27. *M. scalaris*—Three zygospores, a parthenospore and a vegetative cell. Collected in the Douglas Lake region, Michigan, by A. B. Ackley.

Plate III.

Fig. 28. *M. sphaerocarpa*—Zygospore and vegetative cell from material collected at Columbus, Ohio.

Figs. 29, 30. *M. sphaerocarpa*—Aplanospores showing variations, from Columbus, Ohio.

Figs. 31, 32. *M. sphaerocarpa*—Zygospores showing the part of the cell contents left outside the spore contracted about the spore wall.

Fig. 33. *M. sphaerocarpa*—Zygospores occurring in rows, in this instance with two parthenospores, the gametangial walls greatly thickened. This figure is very suggestive of West's figure of *Debarya africana*. See Ohio Jour. Sci. 25:196, Pl. I, Fig. 1.

Figs. 34, 35. *M. sphaerocarpa* var. *varians*—Aplanospore and zygospores from material collected by Walter R. Shaw, Manila, Philippine Islands.

Fig. 36. *M. crassa*—Redrawn to scale after Wolle, 1887.

Fig. 37. *M. ovalis*—Drawn from Wittr. & Nordst. Alg. Exsicc., No. 742.

Fig. 38. *M. macrospora*—Redrawn to scale after Wolle, 1887.

Figs. 39–41. *M. robusta*—Drawn from material collected at Winchester, Mass., July 15, 1908. Fig. 40 shows a spore formed by the union of three gametes of which I have encountered several.

PLATE IV.

Fig. 42. *M. angolensis*—After G. S. West, 1897.

Fig. 43. *M. genuflexa*—Drawn from material collected at Charleston, Illinois, a single pair of filaments showing lateral and scalariform conjugation and genuflexing. Some intervening vegetative cells have been omitted in making the drawing.

Fig. 44. *M. genuflexa*—Zygospore formed by lateral conjugation, showing that the conjugating tube primordia do not necessarily arise in contact with each other.

Fig. 45. *M. genuflexa* var. *gracilis*—Collected at Lerna, Illinois.

Figs. 46–50. *M. laetevirens*—Material collected at Cold Spring Harbor, Long Island, N. Y., August 2, 1924, shows three zygospores and two aplanospores.

Figs. 51, 52. *M. laetevirens* var. *varians*—After Wittrock, Bot. Notiser, 1886, p. 135.

Fig. 53. *M. pulchella*—Material from Douglas Lake region, Michigan. Collected by A. B. Ackley.

Fig. 54. *M. subcrassa*—After G. S. West, 1909.

PLATE V.

Figs. 55–57. *M. notabilis*—Material from Charleston, Illinois.

Figs. 58–59. *M. notabilis*—Material collected by L. H. Tiffany at Spirit Lake, Iowa, July 2, 1923. Showing variations in aplanospores and zygospores.

Figs. 60–61. *M. irregularis*—After West, 1897.

Figs. 62–64. *M. capucina*—Material collected by Wolle, "Mill pond," New Jersey.

Fig. 65. *M. capucina*—Vegetative cells; upper, the usual type; lower, from occasional filaments showing constricted chromatophore.

Fig. 66. *M. capucina*—Material from South Carolina collected by Ravenel.

Figs. 67, 68—*M. capucina*—Material from Wittr & Nordst. Alg. Exsicc. No. 539. Showing division of one, and of both gametes before conjugation.

Fig. 69. *M. capucina*—Aplanospore from Gainesville, Florida, March 3, 1925. Collected by W. M. Barrows.

Figs. 70, 71. *M. quadrangulata*—Aplanospore and zygospore from Gainesville, Florida, March 3, 1925. Collected by W. M. Barrows.

Fig. 72. *M. quadrangulata*—Zygospore showing retuse angles, occasional in a collection from Burgaw, North Carolina, by D. B. Anderson.

Figs. 73–75. *M. paludosa*—Vegetative cells and zygospores. After G. S. West, 1899.

Figs. 76, 77. *M. mayori*—Vegetative cell and aplanospore. After G. S. West, 1914.

PLATE VI.

Figs. 78–80. *M. boodlei*—Aplanospores, zygospore and a vegetative cell. All from the Campus Pond, Charleston, Illinois.

Figs. 81–83. *M. tenerrima*—Vegetative cell and aplanospores. After G. S. West, 1914.

Fig. 84. *M. elegantula*—Aplanospore from Charleston, Illinois, May 31, 1912.

Fig. 85. *M. elegantula*—After Wittrock, 1872.

Figs. 86, 87. *M. elegantula*—Vegetative cell, immature and mature zygospore; Twin Lakes, Michigan, June 2, 1915.

Figs. 88–93. *M. americana*—Vegetative cell, aplanospores and the highly variable zygospores. Oneida Lake, New York, July 20, 1916.

Fig. 94. *M. corniculata*—Vegetative cells and zygospore. After Hansgirg in Kirchner, 1878.

Figs. 95, 96. *M. gracillima*—Aplanospore and zygospores; Oneida Lake, New York, July 20, 1916.

PLATE VII

Figs. 97–98. *M. viridis*—Zygospores and aplanospores; Saugetuck, Michigan, June 1, 1915.

Figs. 99–101. *M. punctata*—Zygospores and vegetative cells; after Wittrock, 1867.

Fig. 102. *M. uberosperma*—Zygospores. After W. & G. S. West, 1898.

Fig. 103. *M. uberosperma*—Aplanospore and vegetative cells. Material collected by Miss E. Stephens, Kentani, Cape Colony.

Fig. 104. *M. virescens*—Zygospore. After Hassall, 1845.

Fig. 105. *M. tumidula*—Zygospore, aplanospore and vegetative cell. Zygospore from Embarras River, Wheeler, Illinois, September 1, 1911; aplanospore from Ocheyedan, Iowa, July 24, 1913, (L. H. Tiffany).

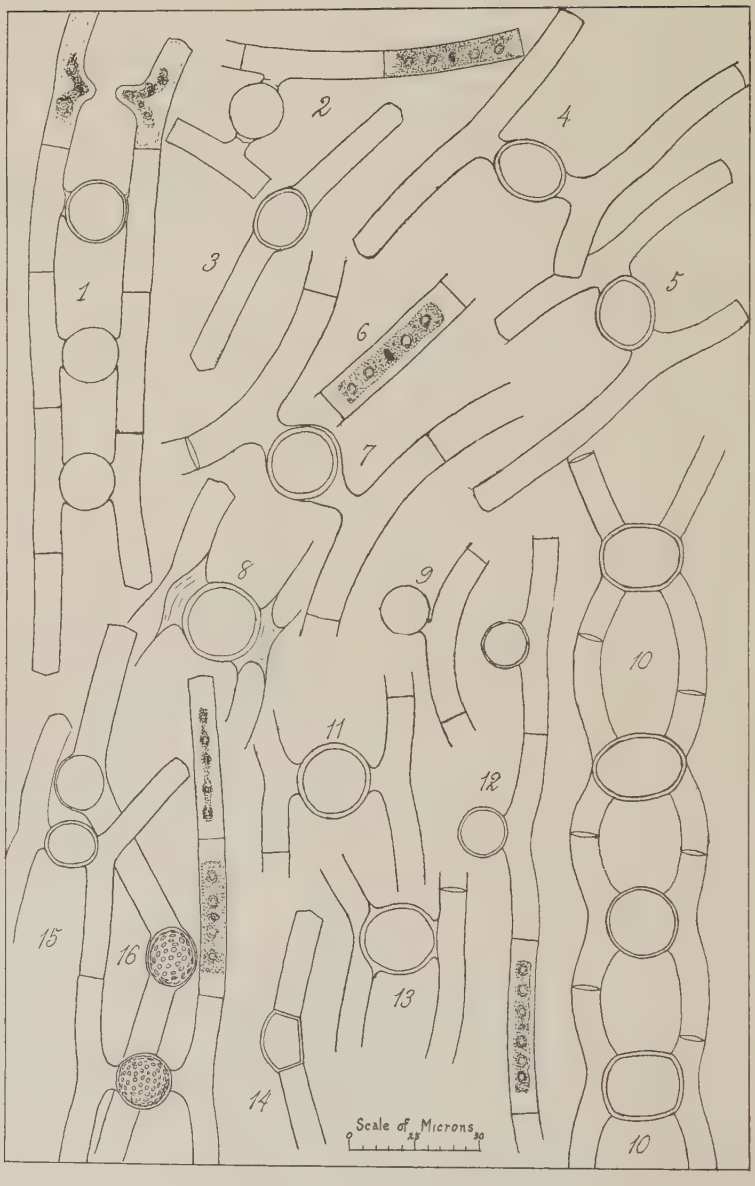
Figs. 106–108. *M. ventricosa*—Vegetative cell and aplanospores. After Wittrock, 1878.

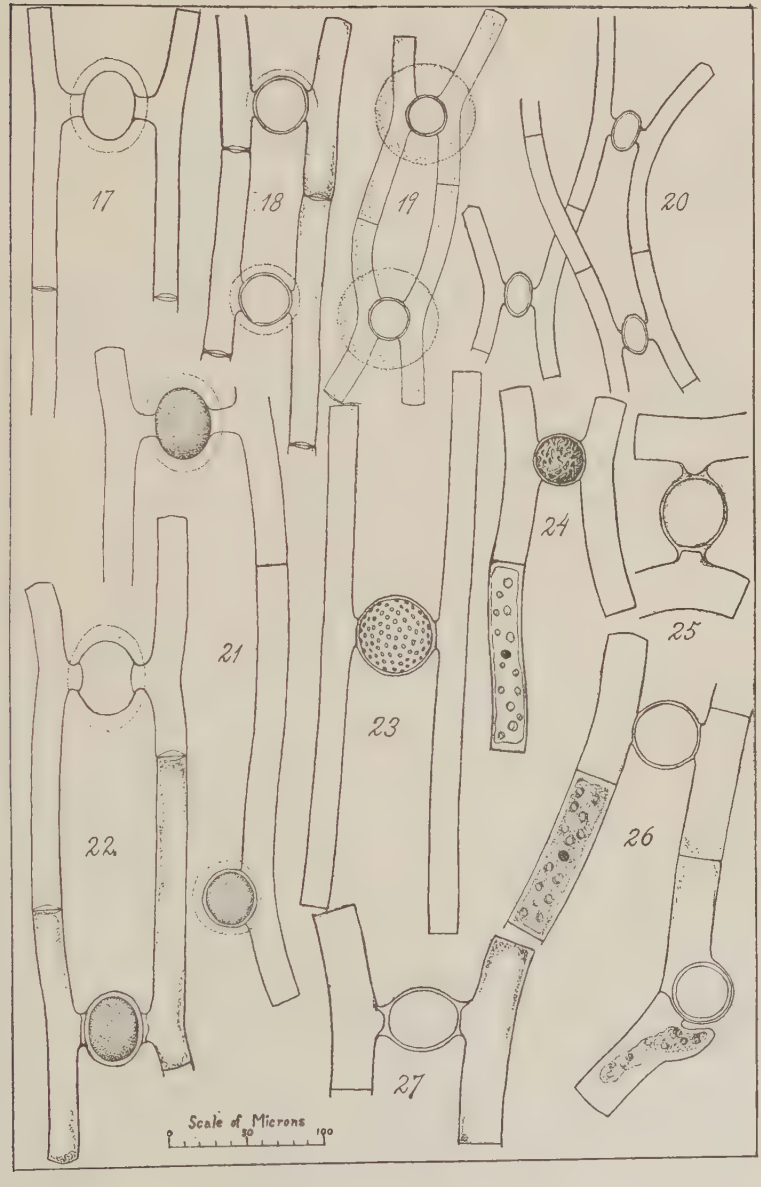
Fig. 109. *M. prona*—Aplanospores showing variations. Long Island, New York, July, 1924.

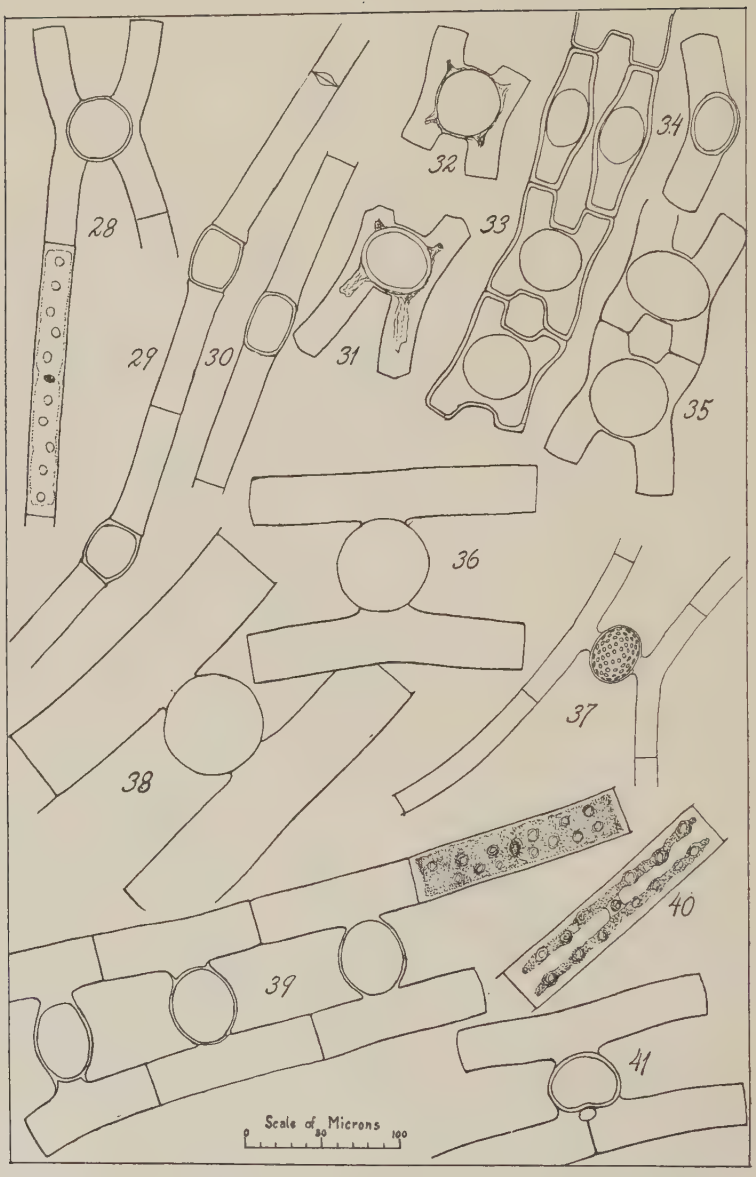
Figs. 110–111. *M. prona*—Vegetative cell and early stage of aplanospore showing division of chromatophore and subsequent gliding of each half into the swollen portion of the cell.

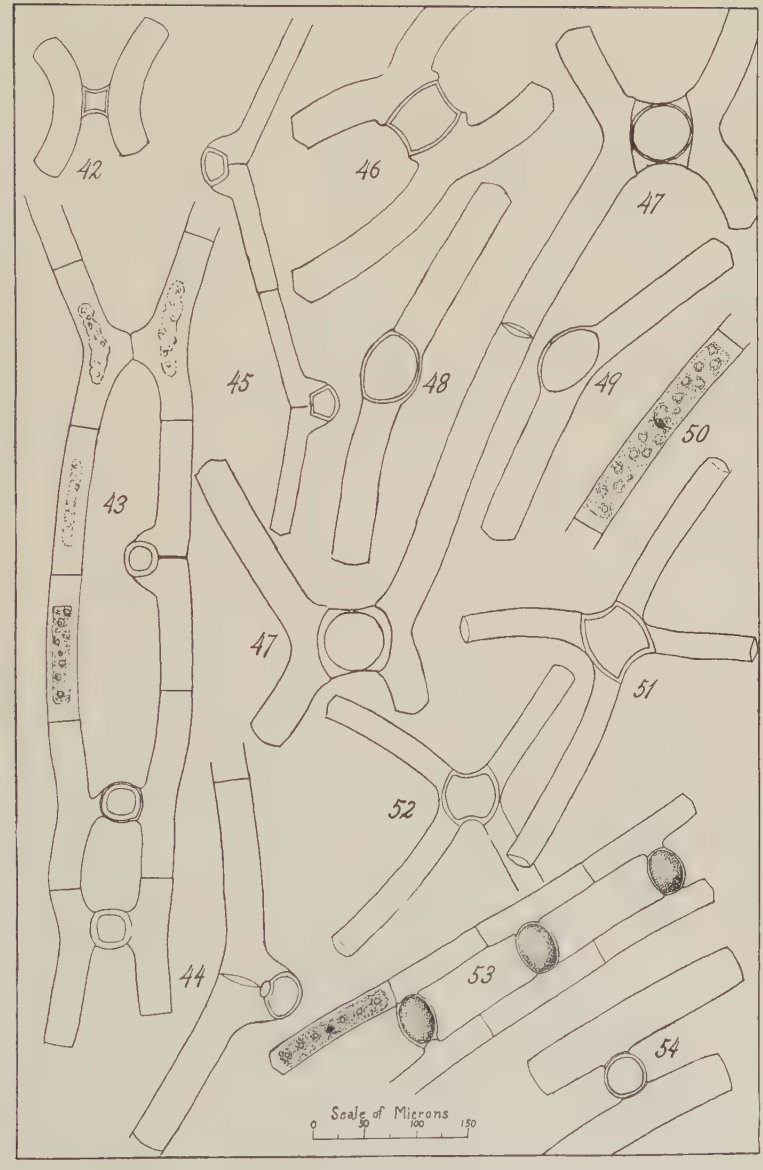
Fig. 112. *M. tropica*—Vegetative cells and aplanospores. After G. S. West, 1916.

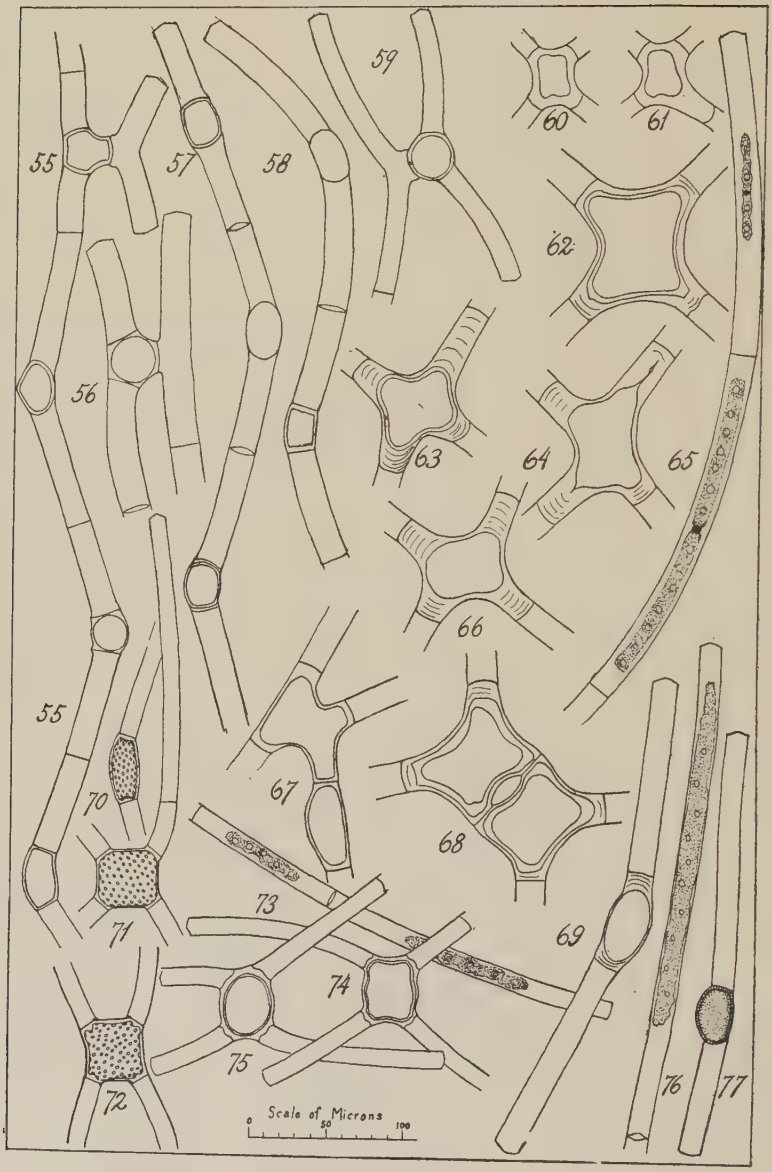
Figs. 113, 114. *M. producta*—Zygospore and aplanospores. After G. S. West, 1907.

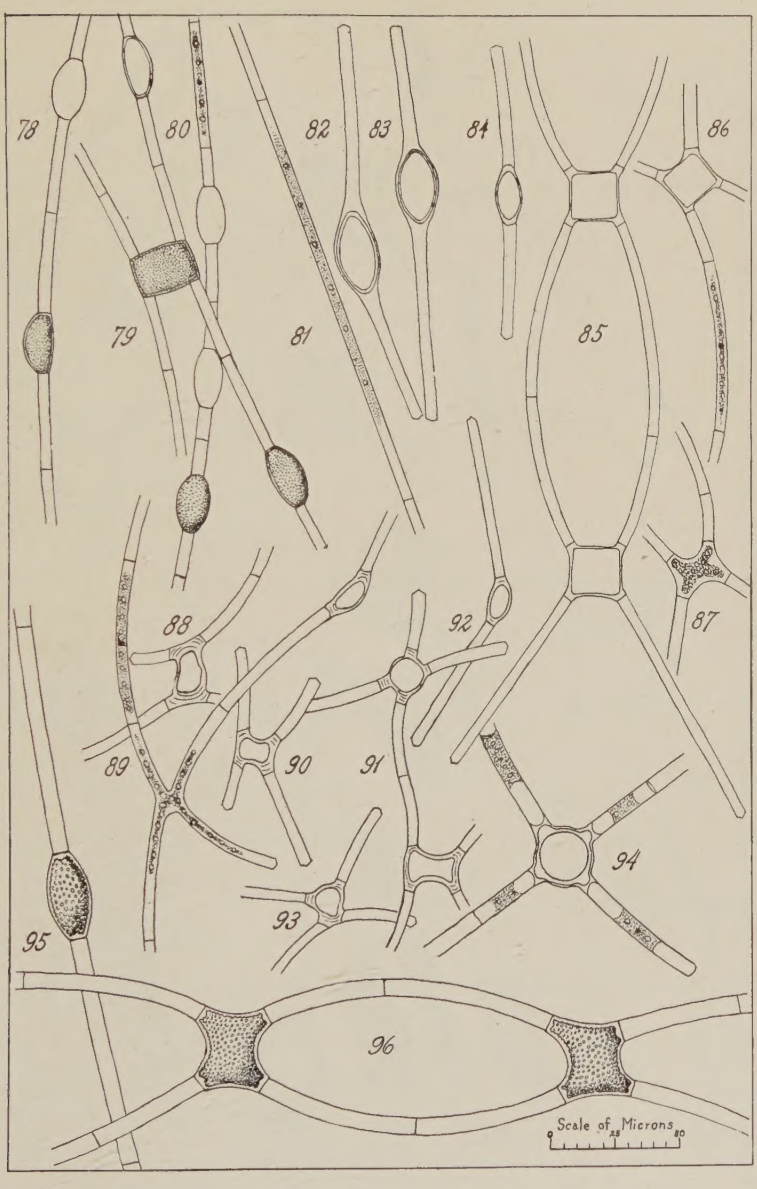

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Scale of Microns
0
25
30
10

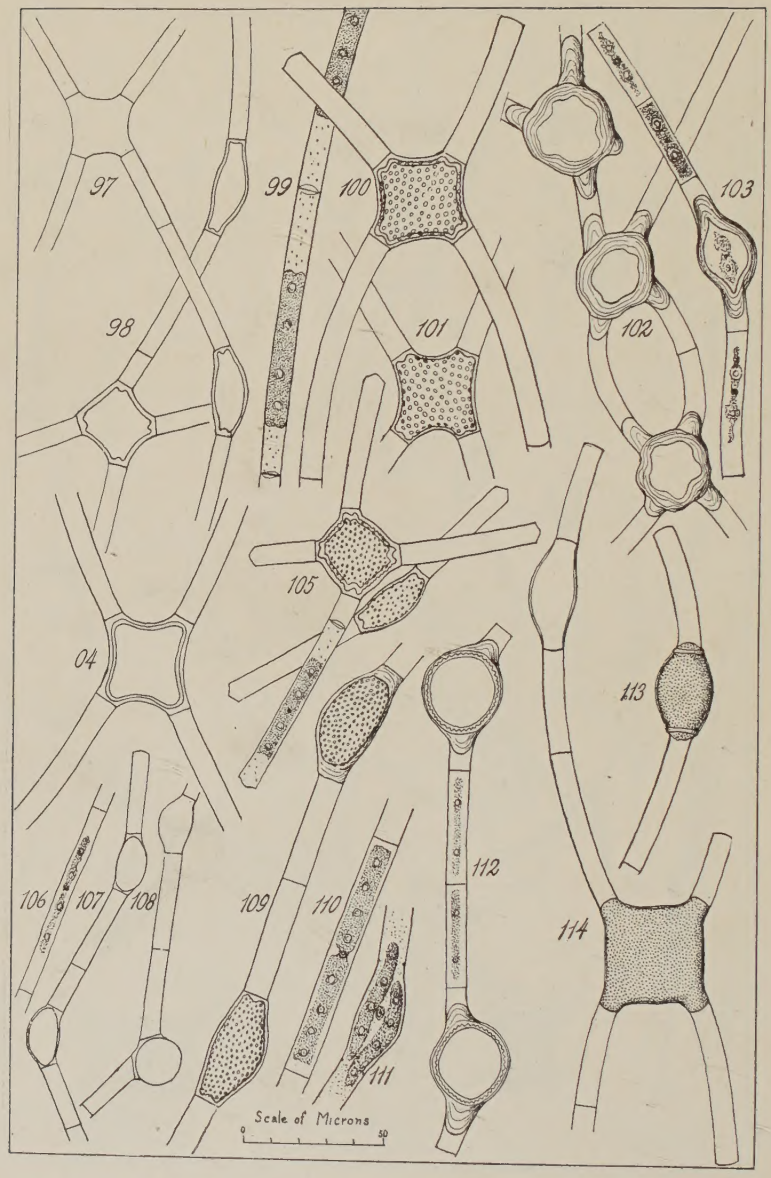

17
18
19
20
21
22
23
24
25
26
27
Scale of Microns
0
50
100


28
29
30
31
32
33
34
35
36
37
38
39
40
41
Scale of Microns
0
50
100


42
46
47
45
48
49
50
43
47
51
52
44
53
54
Scale of Microns
0
50
100
150


55
57
58
59
60
61
62
56
63
64
65
66
55
67
68
70
73
71
69
74
75
72
76
77
Scale of Microns
0
50
100


78
80
82
83
84
86
79
81
85
88
92
87
89
90
91
94
93
95
96
Scale of Microns
0
25
80


97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
Scale of Microns
0
50

INDEX TO VOLUME XXVI

PAGE

Academy of Science, Ohio 183
Accumulation of Energy by Plants 1
Additions to the Catalog of Ohio Vascular Plants 169
ALEXANDER, W. H. 183
Alimentary Canal of Passulus 11
Arisaema triphyllum, Siamese Twins of 276
Asplenium angustifolium, Development of 147

Bombylid Genus Villa 205

Caves and Caverns of Ohio 73

DE LONG, DWIGHT M. 42, 49
Development of Asplenium angustifolium 147

Embryo of Asplenium angustifolium 147
Energy Accumulation by Plants 1
Experimentally Induced Siamese Twins 49

Food Plant and Habitat Notes on Some North American Species of Phlepsius 69
FREER, RUSKIN S. 147

Glass Sands of Ohio 49
Goniobasis livescens, Variations in 25

Habitat Notes on Phlepsius 49
Hexagenia bilineata, Larval Stage 267

Larval Stages of Hexagenia bilineata 267
LEWIS, HAROLD C. 11
Limestone Caves and Caverns of Ohio 73

Mougeotia, the Genus 311

Notes on the Development of Asplenium angustifolium 147

Ohio Academy of Science 183
Ohio Caves and Caverns 73
Ohio Glass Sands 25
Ohio Vascular Plants for 1925 169
Ohio Vegetation 128, 213

PAINTER, REGINALD H. 205
Passulus, Alimentary Canal of 11

PAGE

Phlepsius, Food and Habitat Notes..... 49
Physiology of Stomata of Rumex..... 233
Plant Succession, Ohio..... 213
Plants, Principles of Taxonomy..... 294
Plants, Accumulation of Energy by..... 1
Plants of Ohio for 1925..... 169
Prairies, Ohio..... 213
Principles of Plant Taxonomy..... 294

REA, PAUL M..... 281
Report of the Thirty-sixth Meeting of Ohio Academy of Science... 183

Sands of Ohio..... 25
SAYRE, JASPER D..... 233
SCHAFFNER, JOHN H.....169, 276, 294
Science, Social Significance of..... 281
SEARS, PAUL B.....128, 213
Siamese Twins of Arisaema triphyllum..... 276
Social Significance of Science..... 281
Stomata, Physiology of..... 233
Succession, Plant, in Ohio..... 213

Taxonomy, Principles of in Plants..... 294
The Accumulation of Energy by Plants..... 1
The First Three Larval Stages of Hexagenia bilineata..... 267
The Genus Mougeotia..... 311
The Lateralis Group of the Bombylid Genus Villa..... 205
The Natural Vegetation of Ohio.....128, 213
The Social Significance of Science..... 281
TRANSEAU, EDGAR N.....1, 311
Twins of Arisaema triphyllum..... 276
Type and Variation of Wings in Deltocephaloid Genera..... 42

Variations in the Freshwater Snail Goniobasis livescens..... 49
Vascular Plants of Ohio for 1925..... 169
Vegetation of Ohio.....128, 213
Villa, Bombylid Genus..... 205

WIEBE, A. H.....49, 267
WHITE, GEORGE W..... 73
Wings as Factor in Separating Genera..... 42